LAND USE ALLOCATION IN ZHANGJIAKOU CITY UNDER A SPATIAL AUTOCORRELATION PERSPECTIVE

BY

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THESIS

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ABSTRACT

Previous research has examined the general driving factors for land use allocation or land use changes. However, some areas are under active interaction with other neighboring areas—without considering spatial autocorrelation, the mechanism for land use changes can hardly be properly revealed. Zhangjiakou, Hebei, China is one typical example to include the spatial autocorrelation when we discuss the land use change models, since counties in Zhangjiakou are acting together in the Three North Shelterbelt Development Program, which is implemented in northern part of China since 1980s. With the land use data in 1985 and 2000, as well as the data from Hebei Statistical Yearbook, this paper tries to reveal how governmental interactions, along with other commonly recognized driving factors, have their influence on land use changes, especially forestry increase in Zhangjiakou.

The Three North Project was initiated in 1978, aiming to improve forestry coverage in northern part of China. Zhangjiakou city is included in this national project as well thus local governments in Zhangjiakou are involved in the forestation work under the instruction and requirements of the provincial and central governments. Based on the assumption that county-level governments are aiming at maximizing their revenue when they choose among land uses, this paper provides a theoretical model for county-level governments' decisions in the forestation process. This paper is a systematic combination of a theoretical framework and empirical study, and I use the theoretical model to motivate the empirical specification to test my hypothesis that county-level governments actually interact with each other in the process or forestation.

This paper analyzes the land parcels that are within the 4-mile buffer area along the county borders. The data reveals that the spatial autocorrelation within counties differ from the spatial autocorrelation across counties, which means that across the county borders, the reasons for spatial autocorrelation are not only geographic and economic factors, and the

interaction between the counties may lead to the inter-county spatial autocorrelation as well. Also, the way that the county-level governments choose land use types for each land parcel with different geographic and economic characters also reveals that the county-level governments are interacting with each other and working to maximize their own revenues in the forestation process.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

The issue of choosing and converting land uses has proven controversial in China, and allocating land parcels to different land use types is a problem in China has attracted the attention of researchers for a long time. This topic is so important not only because of the land scarcity, but also because of the land use allocation law and processes in this country. In China, most of the land property belongs to the central government (the Constitution of the People’s Republic of China). Government controls the construction and development of land parcels. Local governments allocate land to specific uses and designate land developers (The Land Law of the People's Republic of China, 1999). Therefore, the land use allocation and conversion process is a reflection of government decisions—the central government provides the overall guidance and different level of local governments are responsible of carrying out the guidance. Without consideration of government policies and decisions, an analysis of the mechanism of land use changes is likely to miss the mark, leaving alone the construction of accurate land use change predictions.

Given that land use conversion process reflects government decision-making in China, the ensuing question is how the land use policy is carried out. According to the Land Law of China (1999), in its outlining of land use policies, the central government sets up the overall goal, but no detailed plan is made from the central government. For example, as for forestry land, the central government of China sets a target for forest cover for each province. Then the ministry of forestry in the province supervises the county governments who establish up and carry out the detailed land use plans. Therefore, for county governments, there could be two kinds of neighborhood effects: the first one is that one region’s increase in forestry area or forestry coverage will lead to its neighborhoods’ decrease. The reason is probably that the ecological benefit created by one region can be enjoyed by its neighborhoods, thus the neighborhood areas will have less incentive to plant more trees. This kind of neighborhood effect is unlikely to been observed in China, since the detailed land use plans are designated to each county, thus county-level governments have to meet their land use goals set up by the central and provincial governments, instead of just enjoying the positive externality created by the neighbor counties. The second kind of possible neighborhood effect is that regions which are near to each other will grow together in their forestry coverage or forestry areas. The mechanism for this observation is probably that county governments are competing with each other in constructing new forests. Therefore, the first question this paper aims to answer is which of these two neighborhood effects is the true case in some land-use conversion areas in China? When I try to figure out if county-level governments' interaction and competition will lead to spatial autocorrelation for forestry increase, I still need to consider some other land use driving factors, including geographical and economic factors because the continuity of these factors may also lead to positive spatial autocorrelation. Therefore, this paper also aims at disentangling governmental interactions from other reasons that may result in positive spatial spillovers.

In recent years, ecological problems have attracted attentions from both the public and the governments in China, and the *Three North Shelterbelt Development Program* is one important national program that aims to improve the ecological condition in the northern part of China. In 1978, according to the proposed planning by the Ministry of Forestry of China, in the northern part of China, nine provinces including Xinjiang, Qinghai, Gansu, Ningxia, Shaanxi, Neimenggu Liaoning, Jilin, and Heilongjiang suffered from an increasing area of desert. Approximately 213 counties were vulnerable to sandstorms. Among all these 213 counties, 105 of them were suffering obvious damages in terms of loss of arable lands and grasslands. More than 16.47 million acres of arable land and grassland were frequently threatened by sand storms in this northern part of China.

Northwestern, central northern and northeastern areas are known as *Three Northern* areas that have little vegetative and plant coverage. *Three Northern* areas are vulnerable to natural disasters, thus the agricultural yield level is relatively low compared to other parts of China. Therefore, the construction of forestry shelterbelt and grassland (which serves as a method to protect forestry areas and provide supplementary ecological benefits) not only yields ecological benefits to the country, but economic importance for local residents, especially the residents working in agricultural industry. According to the Central People's Government of the People's Republic of China (2013), the main objectives and plans for Three North Project can be summarized in Table 1.

Table 1. Main goals and plans for Three North Project

Three North Project: Objectives and Plans	Project Length: 73 years (1978 to 2050)
Involved Area: 4.069 million sq.km (42.4% of Total area of China)	**3 periods and 8 sub periods are involved**
Main objectives:	Three periods: 1978-2000 2001-2020 2021-2050
1. Increase the total forestry area from 0.02314 million sq.km to 0.06084 million sq.km 2. Increase the forestry coverage rate from 5% to 14.95% in the country 3. Increase wood storage from 7.2 hundred million cubic meters to 42.7 hundred million cubic meters 3. In plain and oasis areas, construct forestry protection for arable lands Significantly decrease the land erosion 4. No more growth in the desert area 5. Ecologically improve the living standard for the residents in Three North Area	Eight sub periods: Every ten years since 1978

The Three North Shelterbelt Development Program was approved by the central government in 1978. In addition to the nine provinces mentioned by Ministry of Forestry of

China, Hebei and Shanxi are included in the Three North Shelterbelt Development Program. This program started in 1978, and is expected to end in 2050. The whole program is divided into eight continuous periods: Period 2 (1986 to 1995) and Period 3 (1996 to 2000) approximately coincide with the data period (1985 to 2000) in this research. Zhangjiakou city, which is included in Hebei province, has been included in the Three North Shelterbelt Development Program since 1978. With detailed documents on Three North Shelterbelt Development Program, obvious land use conversion in the program periods, and careful field investigation conducted by Yueqing Xu's research group at the China Agricultural University (CAU), this paper chooses Zhangjiakou as the study area, trying to answer how the county governments interact with their neighbors when allocating land to forest. Figure 1 demonstrates the provinces that are involved in Three North Project. Zhangjiakou city, within Hebei province, is specially marked.

Figure 1. Provinces involved in Three North Project

With land use data and other economic and ecological data in Zhangjiakou city since

1985 to 2000, this paper's main objectives can be summarized as below:

- Create the land use changes dataset for Zhangjiakou city
- Statistically summarize the land use changes in Zhangjiakou from 1985 to 2000
- Give the theoretical model that simulates the forestry changes in Zhangjiakou
- Evaluate the spatial autocorrelation in forestry changes in Zhangjiakou
- Based on above analysis, give implications to Three North Project

The research questions this paper wants to answer are:

- Would the county level governments interact with each other in the Three North Project?
- If the county level governments are interacting with each other in the Three North Project, would this interaction lead to misallocation of new forestry lands?

To answer these two research questions and reach the objectives of this paper, my following work is divided into seven different parts. The first part of this paper is the brief introduction of the study issue. The background of Chinese Three North Project is summarized in part one.

The second chapter reviews the related literature about land use changes. Firstly, theoretical and empirical works related with land use changes in China are reviewed. With the review of previous studies, I try to find out the linkage between my study and existing studies, as well as my unique contribution to this area.

The third chapter of this paper is the description of the study area. First, this chapter gives a brief overview of our study area: Zhangjiakou, Hebei, China. Second, data about the land use changes is presented in detail. According to the description of land use changes, it can be seem clearly that Zhangjiakou has undergone a great increase in forestry land as well as obvious loss in grassland and arable land from 1985 to 2000. The geographic patterns of land use changes will be presented by carefully designed maps generated by ArcGIS 10.0.

The fourth chapter is the conceptual frame to simulate the neighborhood effects among county governments as for changes in forestry land. I present a theoretical model to make hypotheses about the patterns of land use changes in the study area. My hypotheses are going to be tested in later chapters of this thesis.

The fifth chapter of the thesis is the model specification. In this chapter, I will relate my theoretical model with the empirical tests that will be carried on in Chapter 6.

Then the sixth chapter of this paper is empirical tests. With the theoretical basis and the data, Chapter 6 supports my theoretical model by running OLS regressions, doing specification test, and finding out an appropriate spatial model which demonstrates spatial autocorrelation as for forestry increase in Zhangjiakou.

Finally, the seventh part is discussion section and conclusion section. Based on above analysis, this paper gives implications to Three North Project and similar land use projects in China.

Now, I will review related literature and policies in the coming chapter.

CHAPTER 2

LITERATURE REVIEW

With the research goal to evaluate the driving factors of the land use changes in Zhangjiakou city, this paper reviews previous literature regarding land use changes theoretically and empirically. This part of the thesis is be divided into two parts: firstly, I will review previous literatures on land use and land use changes. Secondly, I will review literatures on governmental interaction, especially the governmental interaction in China under the current political structure.

2.1 LITERATURES ON LAND USE CHANGES

In the field of land use change or land use re-allocation, some theoretical studies are quite similar to Zhangjiakou case. Newburn et al., (2006) incorporate an explicit land-use change model and hedonic price models to provide the targeting strategy for the conversion of land uses. The authors' assumption is that land costs and probability of land-use conversion may have a positive correlation. The land use conversion (defined as transition from developable parcels to either residential or vineyard) is estimated by multinomial logit model and the valuation of developable land is estimated by using hedonic price model. Both the multinomial logit model and the hedonic price model are using the same set of explanatory variables. The authors of this paper find that steep slope, high elevation and the existence of floodplain are likely to reduce land parcels' probability of being converted into residential land and vineyard land, mainly because of the high conversion cost and the difficulties of future maintenance. However, lands with easy access to urban services are more likely to be converted into residential use, and have higher valuation as developable areas. In short, land parcels with different characters have different conversion costs and conversion threats, thus the probability for land use conversion would differ as well. Not only for the development of residential areas and vineyards, Newburn et al., (2005) also put forward a benefit-loss-cost targeting approach for site-selection process of conservation lands. They compare their targeting approach with traditional strategies.

Alix-Garcia (2007) provides a systematic combination of theoretical and empirical analysis of the deforestation process in Mexico. Within his theoretical work, each community is working to maximizing its revenue from the land use change of converting forestry land to pasture land. The probability of converting forestry land to pasture land depends on the community's total demand for pasture land, the land parcels' physical characteristics within this community, and the relative profitability of pasture land. The main implication of Alix-Garcia's research is that plots' land characteristics, as well as communities' demands for land conversion, jointly affect plots' probability of deforestation. Alix-Garcia's study throws much light on land use studies in China, especially this Zhangjiakou study, since it can been seen in the statistical summary part of this thesis that Zhangjiakou's increase of forestry land is at the expense of the loss of agricultural land. Therefore, land characteristics that affect the relative land values in forestry use and agricultural use should be considered when analyzing the mechanism of land use changes.

Also, there are some other studies pointing out the possible driving factors for land use changes in Zhangjiakou. Generally speaking, some ecological and economic factors are frequently mentioned as driving factors of land use changes. For instance, using the logistic model, Serneels and Lambin (2001) target distances to developed areas, distances to water, distance to road systems, elevation, population density, land tenure and soil suitability as significant factors which contribute to land use changes in Narok Distrct, Kenya. In their research, they concentrate on three types of land uses: mechanized agriculture, rangeland and smallholder agriculture. Even though their research does not pay much attention to forestry reservation site selection, their finding is valuable for this paper since they thoroughly examine the ecological and economic factors leading to land use changes. These factors generally influence not only the distribution of arable sites, but the forestry distribution as well.

Similarly, Jantz et al., (2004) simulate three future policy scenarios (current trends, managed growth and ecologically sustainable growth) when they analyze the Baltimore-Washington metropolitan area. Their model offers one strong planning tool which can visualize future scenarios when different levels of policies are implemented. The SLEUTH (slope, land use, exclusion, urban extent, transportation, and hillshade) model in their research is one strong method if we want to choose among future alternative policies. However, this model does not work directly in evaluating currently existing policies. Moreover, their paper does not consider spatial autocorrelation in their regression. The above mentioned land use driving factors are commonly recognized and also have been applied in empirical studies in China.

As for China, there are many other researches about land use change in China since 1978. However, most of them are purely statistical descriptions of land use changes, or qualitatively point out the driving factors of land use changes. Land use models including the policy effects are to be developed in forthcoming researches. Fischer and Sun (2001) concentrate on methodologies to analyze land use change in China. They suggest that input-output analysis can be used to assess different future land-use policy alternatives, but how to model the current land-use allocation with the national policy factor still remains unclear.

An increasing number of studies in China are focusing on proving the commonly recognized factors that can lead to land use changes. Numerical studies are about land use issues, especially land use changes with emphasis on the fact that tremendous urbanization and industrialization processes generally encourage the growth of township and some small industries (Liu et al., 2003) and become the key factor for land use changes (Xiao et al., 2006;

Long et al., 2007; Seto and Kaufman, 2003; Xu, 2004). For instance, Xiao et al., (2006) based their research on Shijiazhuang, which is in the same province as Zhangjiakou. In their research, they divide the land use in Shijiazhuang into three types: special objective (military establishment) oriented type (1934 to 1947), socio-political intervention type (1958 to 1976, in this period China carried on Great Leap and Cultural Revolution.), and normal growth type (after 1976). In all these different types, urbanization in Shijiazhuang is driven by different main factors. To be more specific, the main political driving factors for urbanization are respectively military establishment requirement during war period (urbanization in this period was governed by the establishment of military base and associated other uses), political situation (urbanization was strongly affected by political activities including Great Leap Forward and Cultural Revolution) and economic development and population growth (urbanization was influenced by high speed economic and population growth after 1978). Similar to Xiao's study, other papers specifies urbanization and industrialization processes are driving factors since China has been undertaking important economic and developmental reforms since 1978. Liu et al., (2003) discuss the key human driving forces, including policies, for land use changes. However, these previous studies generally discuss policies related to urban expansion. Few of them have discussed how national forestation programs, among which Three North Program being the most famous and lasting one, could have their impact on the patterns of land use changes.

When researchers look at land issues, land use externality is always considered as a possible factor that promotes land use changes. From an economic perspective, the forestation process in each county may lead to a positive externality (Pigou, 1920). To be more specific, the increased forestry area within one county not only provides positive ecological benefit for this county exclusively, but also provides ecological benefit for neighbor counties as well. For instance, the formation of new forest can provide a lot of ecological benefits including preventing sandstorms, improve soil quality, changing local climate and improving the air quality. Theses ecological benefits can only be generated with continuous forestry areas, instead of separated trees. Actually, the externality of land use changes is not confined to forestry use. Irwin and Bockstael (2004) focus on the land use externality and its effects on urban development and the local policies aiming at managing urban growth and preserving open space. According to their analysis, local policies have both direct and indirect effects, and indirect effect, arising via land use externalities when land parcels' development values change when policies induce land use changes to their neighbor parcels, is found to be positive and significant, speeding up the sprawl pattern of urban development. In Zhangjiakou's case, even though I am not looking at urban development, but externality is still expected to exist since land parcels and even counties that are near to each other would naturally have some degrees of interactions, no matter whether there are any policy factors or not. For instance, once a county works to improve the forestry coverage, the ecological benefit would be enjoyed by this county and its neighbor counties. If the county-level governments are competing in the forestation process, they should have the incentive make the positive externality internal, instead of sharing the externality with their neighbors.

Besides these commonly recognized driving factors, the spatial spillover effect is also a possible reason for land use changes. Previous researchers have found evidence for spatial autocorrelation in land use change processes, and figured out the reasons leading to spatial autocorrelation. For instance, Nelson and Hellerstein (1996) control for spatial dependence when they decide whether road construction will lead to deforestation. After that, many researches have considered the spatial autocorrelation when discussing land related issues. For example, Conway et al., (2010) control for autocorrelation when they examine the effect of urban green space on residential property values. The authors assume that residential values are naturally autocorrelated. Therefore, by using a spatial lag model, spatial autocorrelation is controlled when the authors try to look at green space's effect on residential property values. The result of the spatial lag model indicates that there is a significant positive relationship between one region's house values and its neighbors' house values. Their research demonstrates that immediate neighborhoods have some similarity as for land values and land characteristics. Deng et al., (2009) attempt to find the relationship between economic growth and the expansion of urban core areas. By conducting a Moran's I test, the authors find strong spatial autocorrelation among neighboring counties when they analyze urban expansion. Using the spatial lag model, the authors find that there is a positive relationship among different counties in the process of urban expansion. However, there are few papers on land use changes attribute the land spatial autocorrelation to governmental interactions.

The above studies about land use changes contribute to this paper in several ways: firstly, I learnt the theoretical framework that based on multiple levels, including the land parcel level and community (or other administrative divisions like county or district) level; Secondly, these studies point out the commonly considered factors for land use changes. By reading these literatures, we understand how the land use changes can be related with some certain land characteristics.

2.2 LITERATURES ON GOVERNMENTAL INTERACTION

Aside from the literature on land use changes, how governmental interactions would lead to spatial effects has been discussed widely. The modeling of governmental interactions on ecological decisions can be dated back to Hoel (1991). Hoel's paper concentrates on the issue of pollution emission, and there are two possible frameworks, respectively non-cooperative games and cooperative games, which can provide a theoretical basis for the emission reduction interactions between two countries. Following Hoel's model, Yu et al., (2011) investigates the determinants of public infrastructure spending in China. Their non-cooperative model is the theoretical basis for their empirical study, which shows that one city responds negatively to an increase in its neighbor cities' infrastructure spending. Even though Yu's work is not about environment protection, it allows us to briefly understand how local governments operate in China. Therefore, it is possible that governments, especially county-level governments and provincial governments are actively interacting with each other thus will lead to some spatial spillover effects.

The cooperative and non-cooperative frameworks are certainly not the only way to model governmental interactions. Brueckner (2001) looks at communities in Boston metropolitan area regarding their decisions in property tax rate. The author sets up the reaction function for a representative community, and the property tax rate is related with this community's certain characteristics (e.g., population, income level), as well as the property tax rates of the competing communities. The author uses the combination of a Tiebout model and a tax-competition model to motivate the empirical test, which is a spatial lag model. The author finds that this representative community has a nonzero slope for the reaction function, which means that interactions between communities exist when they set up the property tax rates. As for the question of taxation rate setting, Brueckner admits that his model is not the only way to model governmental behaviors. By using the Yardstick model, Besley and Case (1992) point out voters would look at public services and taxes in other jurisdictions to help judge whether their government is wasting resources. After that, the voters would decide if their governors deserve to be voted out of office. The empirical model supports the theory, and shows that neighbor governors' tax rate would affect the probability of incumbent reelection and on tax setting behavior.

The above studies show that governmental interaction is quite likely to occur no matter whether there is an official contract to enforce this interaction or not.

When we look at recent studies in China, we can find several papers concerning local governments' interaction, especially competition, when they carry out the policy directives from higher level of governments.

Zhou (2004) builds up a theoretical model to analyze the reason for the failure in local governments' economic cooperation. Zhou points out that the governors from the same level are involved in a political tournament. From 1980s, the promotion of local governors put more emphasis on their achievements, which can be measured by GDP growth, public investment, and other indicators. Also, in the political tournament, the promotion of a governor would directly lower other governors' chances of getting promoted. Therefore, local governors would compete for both the economic indicators as well as the chances of getting promoted. Eventually, under current political structure, local governors do not have the incentive to cooperate.

If we want to find out how local governments would interact with each other for environmental issues, we have to review and develop an understanding of how different levels of governments operate in the Three North Project. According to the Central People's Government of the People's Republic of China (2009), the central government makes the national plan about the Three North Project, and assigns goals to every province involved. Provincial governments specify the goals to each county, and the county-level governments carry out the central government and provincial governments' plans. Also, the central government and provincial governments make up the assessment system to measure the county-level governments' performance for their forestation work.

Recent studies indicate that the county-level governments are more likely to compete rather than cooperating with each other for environmental issues. In recent years, protecting the environment and accomplishing required ecological projects have become very important factors in the governors' assessment system (Qian, 2012). To stand out in the governors' assessment system, county-level governments probably work to exceed the level of performance of their peers. In other words, developing more forestry land, for the county-level governments, is not only one method for ecological improvement, but also one way to distinguish themselves among other county-level governments, and some political benefits may accrue through the process.

Moreover, Yang et al.,(2008) concentrate on local governmental competition and environmental policies in China. They point out that under current tendency of fiscal decentralization and the evaluation system of governors, local governments would compete with each other under the motivation of attracting more mobile capital and labor, as well as preventing local resources from moving out. Eventually, a county or province would respond positively to their neighbors' increase in environmental investment. Based on the motivation to maximize local economic and political benefit, local governments may spend more capital and labor in environmental improvement, but the environmental problems are still unsolved.

From the above literatures, we can see that governmental interaction is likely to occur, especially under the current political structure in China. Previous papers generally point out local governments' motivation for competition. In my study, I will firstly see if there is evidence of governmental interaction, especially competition. Then I will demonstrate if this interaction would lead to misallocation of new forestry lands or not.

After the literature reviews, we can see that this paper is one valuable addition to previous researches in three ways:

First, as for the issue of land use changes, the theoretical basis for the local county-level governments' actions is also unclear. Therefore, this paper will construct a theoretical model based on the assumption that the county-level governments are maximizing revenue subject to the constraint that they set aside a certain percentage of their land for forestry use.

Second, considering spatial autocorrelation, to support the theoretical basis, this paper will give an empirical test to show whether my theoretical model and the related hypotheses can be demonstrated with data from Zhangjiakou city.

Thirdly, this paper will work as the first step to discover the county-level governments' interactions during some nationally initiated programs in China. Later studies can either further support the contention of governmental interactions or construct methods to assess whether the interactions actually deviate from the original purpose of the national programs.

Lastly, this is the first systematic theoretical and empirical study about the Three North Project. This paper allows public to discover the current status of the results from this long-lasting national project in China.

CHAPTER 3

STUDY AREA

This part of this paper provides a statistical summary of my study area—Zhangjiakou, Hebei, China. The statistical summary is divided into several parts: firstly, there is a brief description of our study area; secondly, land use changes from 1985 to 2000 are summarized. Thirdly, some economic and ecological factors are summarized since they are the potential factors for land use changes in Zhangjiakou.

3.1 DESCRIPTION OF ZHANGJIAKOU

The study area of this paper is Zhangjiakou city (39’30’~42’10’ N., 113’50’~116’30’ E.), Hebei, China. Hebei province, as already shown in Figure 1, lies in the northern part of China. Zhangjiakou city is in the northwest part of Hebei province. Zhangjiakou city has 13 counties in total, and the total area for Zhangjiakou city is 37000 sq.km. The total population in Zhangjiakou is 4.5 million, and 3.1 million people are engaged in agricultural industry.

Zhangjiakou city can be ecologically categorized into two parts. Counties Guyuan, Kangbao, Zhangbei and Shangyi belong to a high altitude plateau called Bashang. The altitude in the Bashang area is approximately 1300-1600 meters. The other nine counties are in the area called Baxia. The altitude in Baxia area is approximately 500- 1200 meters. In Baxia area, even though the altitude is lower than Bashang, the landscape is more sloped. Bashang and Baxia areas are adjacent, but they are geographically separated by the Daqing (previously called Yin) mountains. The distribution of counties in Zhangjiakou city can be shown in Figure 2.

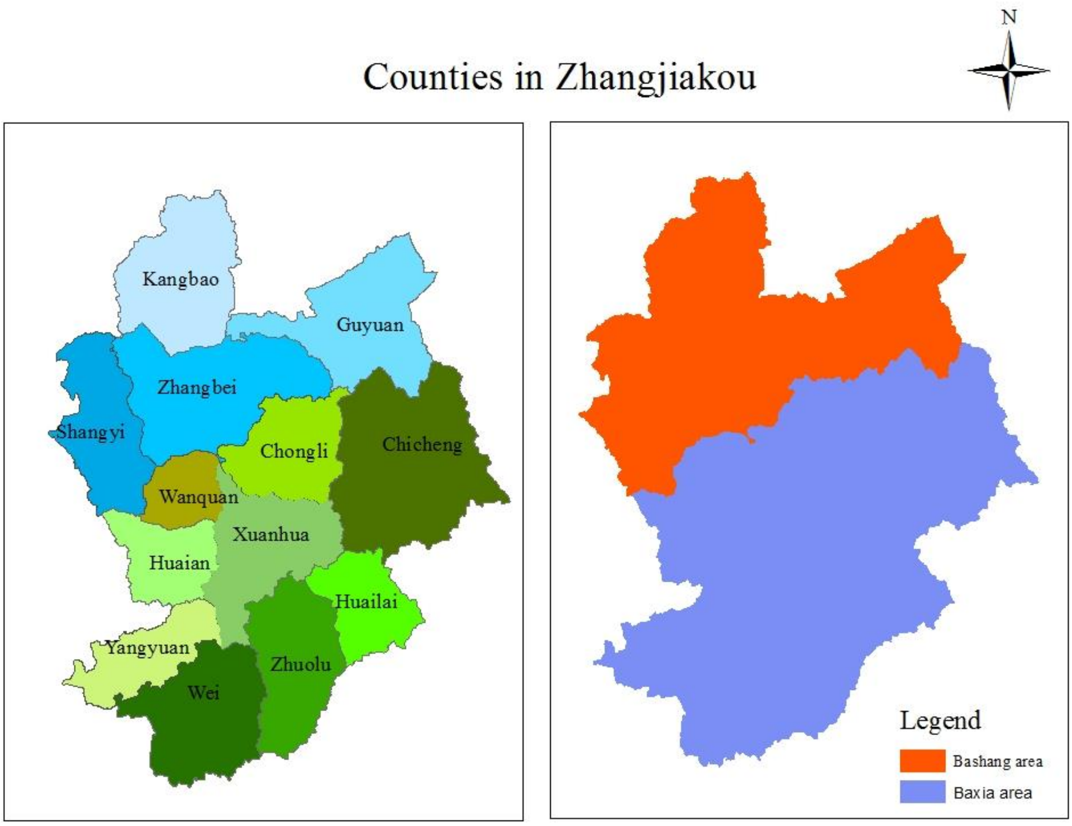


Figure 2. Counties in Zhangjiakou city

3.2 LAND USE CHANGES (1985 TO 2000) IN ZHANGJIAKOU

The data analyzed in this research project is from Professor Yueqing Xu, China Agricultural University (CAU). Land-use data is available respectively in 1985, 1995 and 2000. The original data is vector data. To prepare the data for analysis, the data are dissolved ito layers based on land-use types. In this project, land use types are defined as arable land, forestry land, grassland, water, urban & mining & residential land and undeveloped land according to Chinese land-use category system.

Several GIS techniques have been utilized in this final project. First, with the GIS technique of Change Detection Using Vector and Raster Data, I detect the land-use conversion from 1985 to 2000 in Zhangjiakou. Due to the availability of data, the author divides the whole time period into two, which are 1985 to 1995 period and 1995 to 2000 period respectively. With a thorough understanding of the data and the local land-use conversion tendency, I primarily concentrate on three main land-use types in Zhangjiakou: agricultural land, grassland and forestry land. The land use distribution respectively in 1985, 1995 and 2000 can be seen in Figure 3.

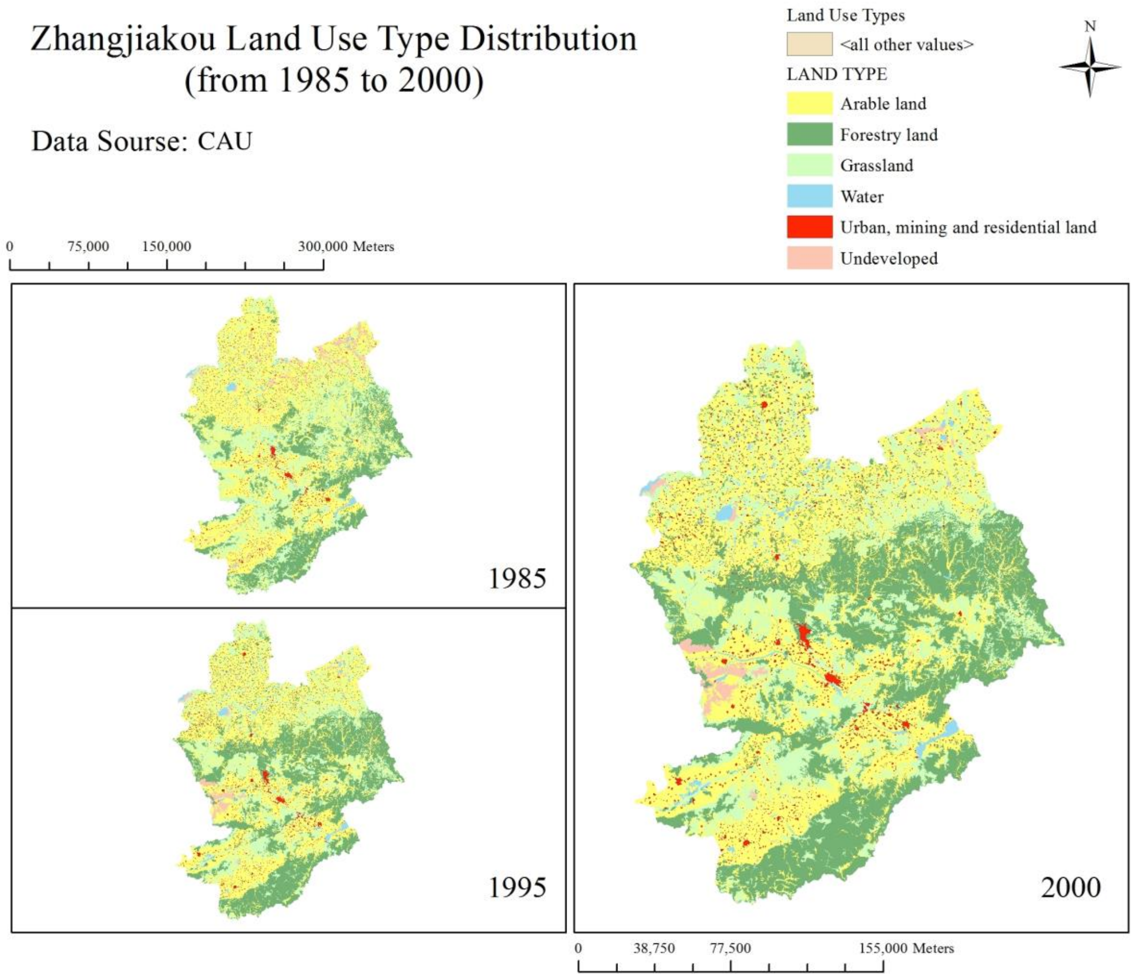


Figure 3. Land use distribution map in 1985, 1995 and 2000

It can be seen from Figure 3 very clearly that the land-use conversion trend in Zhangjiakou area from 1985 to 2000 has two main characteristics. Firstly, this 15-year period features an obvious increase in the area of forestry land, at the expense of arable land and grassland. Especially when we focus on the land parcels in the middle area of Zhangjiakou, there is a propensity for arable land and grassland to transition into forestry land.

It can also be seen from Figure 3 that from 1985 to 2000, the middle area of Zhangjiakou has developed into a continuous forestry area. However, in the northern part of Zhangjiakou, the Bashang area, the forestry area has been increasing from 1985, and forestry lands distribute relatively sparsely compared to the middle area, and no continuous forestry area has been created.

Also, Figure 4 illustrates that most of the land use changes in Zhangjiakou takes place in the period of 1985 to 1995. Therefore, the land use distribution remains fairly stable from 1995 to 2000. In order words, no obvious forestry increase takes place in the last five years of our study period.

Figure 4 summarizes the specifics of the data on land use changes in Zhangjiakou city from 1985 to 2000.

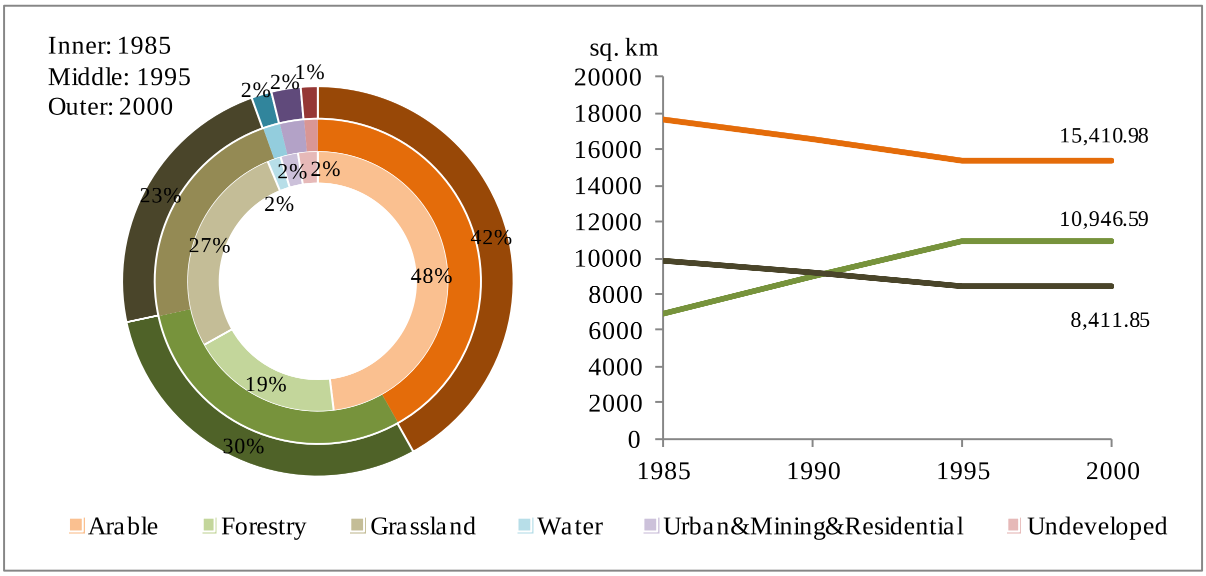


Figure 4. Statistical summary of land-use conversion characteristics from 1985 to 2000

Statistically, the forestry land constituted 19% of the total land area in 1985, while this percentage jumps to 30% in 2000. Over the same time, the percentage of arable land has decreased from 48% to 42%; the percentage of grassland has decreased from 27% to 23%.

Most of the land-use conversion took place during 1985 to 1995. During 1995 to 2000, there was no obvious conversion. In order to more specifically demonstrate the land-use conversion process, the following transition matrix can be constructed.

Table 2. Land-use transition matrix in Zhangjiakou from 1985 to 2000

Unit: sq.km	Arable	Forestry	Grassland	Water	Urban&Mining&Residential	Undeveloped
Arable	14096.6	1499.7	1816.5	100.9	89.2	78.1
Forestry	164.4	6031.7	692.8	2.4	2.2	29.4
Grassland	856.5	3332.7	5331.6	22.4	28.7	303.3
Water	96.6	26.7	33.1	454.7	1.3	1.6
Urban&Mining&Residential	24.4	5.6	8.2	0.3	761.2	1.0
Undeveloped	172.6	50.4	529.8	35.1	7.8	101.0

Table 3. Land-use transition percentage matrix

Unit: sq.km	Arable	Forestry	Grassland	Water	Urban&Mining&Residential	Undeveloped	Sum
Arable	79.73%	8.48%	10.27%	0.57%	0.50%	0.44%	100%
Forestry	2.37%	87.13%	10.01%	0.03%	0.03%	0.42%	100%
Grassland	8.67%	33.75%	53.99%	0.23%	0.29%	3.07%	100%
Water	15.73%	4.34%	5.39%	74.06%	0.21%	0.27%	100%
Urban&Mining&Residential	3.05%	0.70%	1.02%	0.04%	95.07%	0.13%	100%
Undeveloped	19.25%	5.62%	59.09%	3.92%	0.87%	11.27%	100%

As it can be shown from Table 3 that 8.48% of arable land and 33.75% of grasslands have transitioned into forestry land from 1985 to 2000. Therefore, the data here support the conclusion from the land use distribution map that the increase of forestry land is primarily at the expense of the loss in arable land and grassland.

Aside from the changes in forestry land, in the below figures, I demonstrate the conversions of arable land and grassland respectively. With the below figures, one can easily recognize the pattern of land use changes that occurred from 1985 to 1995.

Change in Arable Land from 1985 to 2000

Arable increase
Arable decrease

Data source: CAU

Arable land's Conversion to:	Area (sq.km)	% of Total conversion
Forestry Land	1499.7	41.84%
Grassland	1816.5	50.68%
Water	100.9	2.82%
Urban&Mining&Residential	89.2	2.49%
Undeveloped	78.1	2.18%

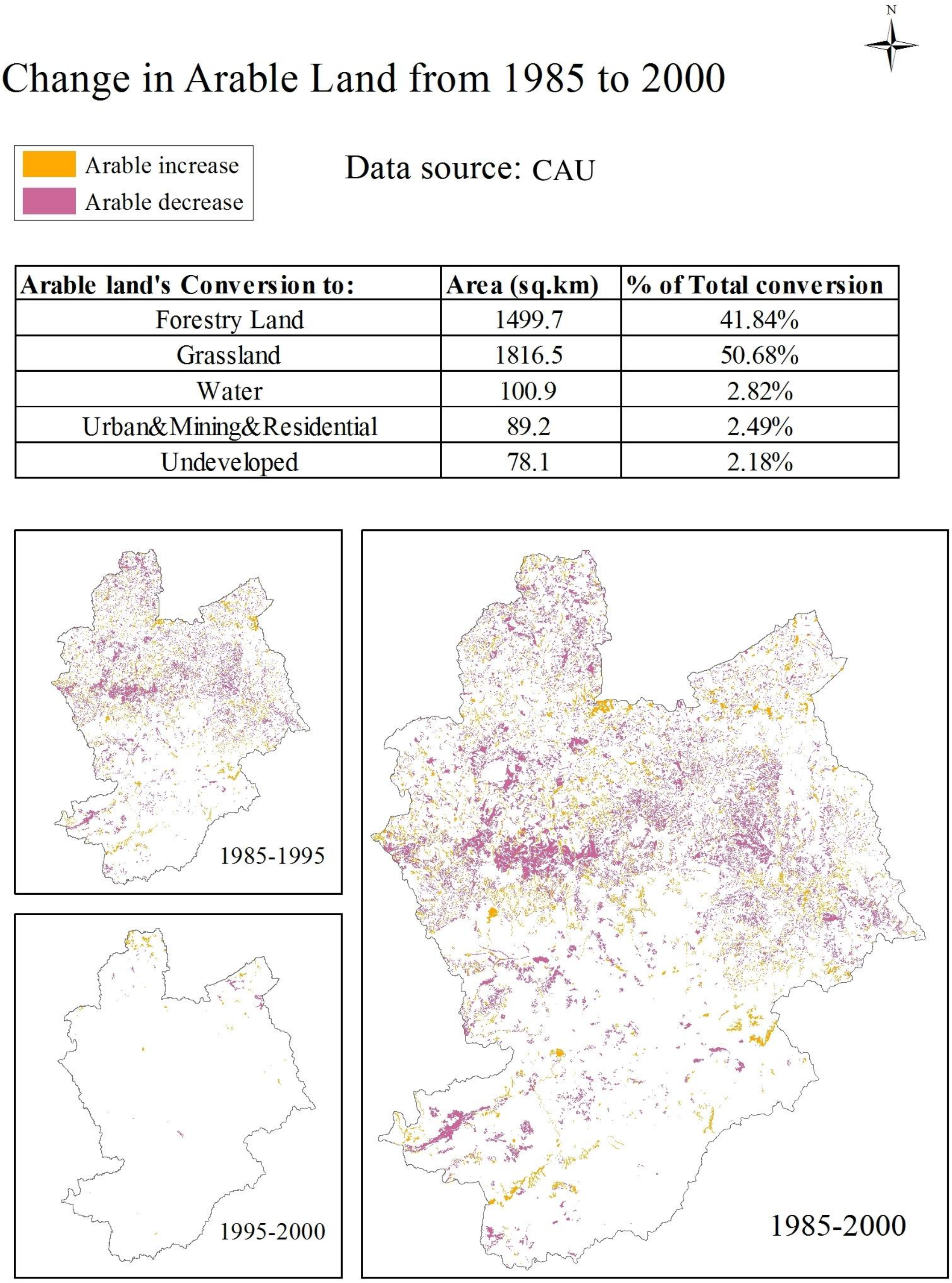


Figure 5. Arable land changes from 1985 to 2000

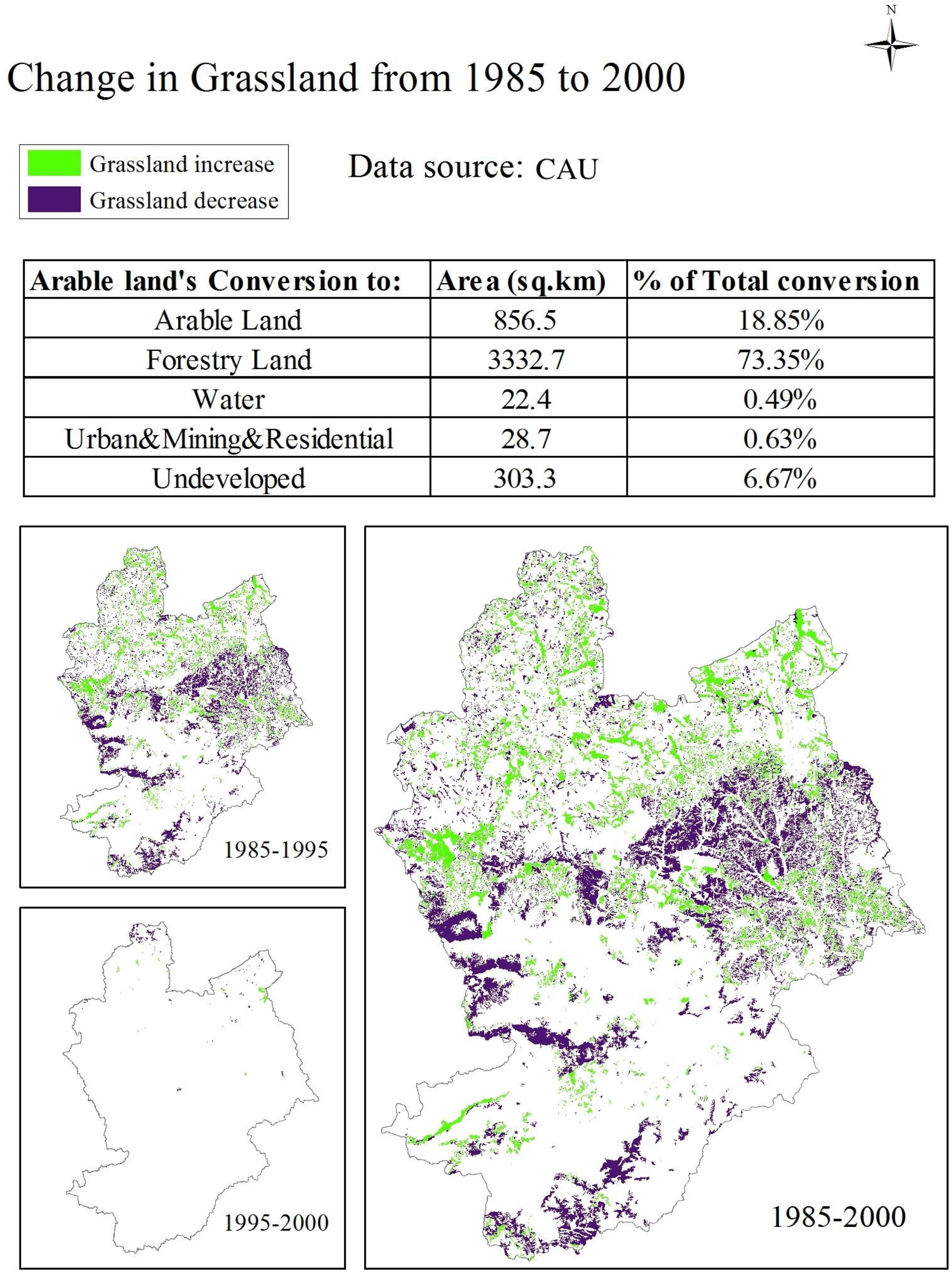
It can be seen from Figure 5 that Zhangjiakou city experienced an obvious decrease in arable land from 1985 to 2000. 41.48% of the converted arable land has been developed into forestry land, and 50.68% of the converted arable land has become grassland. Therefore, from

1985 to 2000, there is a tendency that previous arable land parcels converting into grassland and forestry land.

Geographically speaking, it can be seen from Figure 5 that most of the arable land loss takes place in Bashang area. The sites where arable land has been decreasing are sparsely distributed across the Bashang area. This distribution is similar to the distribution of forestry increasing sites from 1985 to 2000—even though the Bashang area does not form a continuous forestry area, newly developed forestry sites are quite evenly and sparsely distributed. For the Baxia area, even though some loss in arable land can also be detected by Figure 5, the amount of loss is not so obvious compared with Bashang area.

Also, compared to the second time period 1995 to 2000, the first period 1985 to 1995 has witnessed most of the arable land loss. From 1995 to 2000, the land use situation remained stable, with no significant changes taking place in this time period. This pattern mirrors forestry increasing process in Zhangjiakou.

In summary, our study time period 1985 to 2000 has shown an obvious arable land loss in Zhangjiakou area, especially in the Bashang area.



Arable land's Conversion to:	Area (sq.km)	% of Total conversion
Arable Land	856.5	18.85%
Forestry Land	3332.7	73.35%
Water	22.4	0.49%
Urban&Mining&Residential	28.7	0.63%
Undeveloped	303.3	6.67%

Figure 6. Grassland changes from 1985 to 2000

As it can be seen from Figure 6, two patterns of grassland changes can be observed clearly. Firstly, in the middle area of Zhangjiakou city, there is an obvious decrease in grassland. According to the previous analysis of forestry land changes, the decreasing sites of grassland in middle Zhangjiakou are approximately the same sizes as increasing sites of forestry land. Also, in the Baxia area, we see some loss in grassland, and the distribution of the grassland loss is quite similar to the distribution to new forestry land in Figure 3.

As for the Bashang area, we can see both grassland increase and grassland decrease. There are grassland increasing and decreasing sites across the Bashang area.

In summary, tremendous loss in arable land and grassland can be found in Zhangjiakou from 1985 to 2000. The Bashang area has experienced more changes than the Baxia area. Also, compared with arable land, the pattern of grassland decrease corresponds closely at the site level to the pattern of forestry land increase.

To capture the mechanism of the land use changes, especially the forestry increase in Zhangjiakou city, I will formulate a land use change model in Chapter 4. After that, I will describe the variables that I will use in the empirical model in order to test my theoretical model.

CHAPTER 4

LAND USE MODEL

In Chapter 4 of this paper, I will firstly demonstrate a theoretical basis that can explain the mechanism of land use changes in Zhangjiakou. Later, I will describe the independent variables that I will use in the empirical model that supports the theoretical model.

4.1 THEORETICAL BASIS FOR LAND USE CHANGES IN ZHANGJIAKOU

Formally, if the county level governments need to decide forestry coverage within each land parcel, governments are maximizing the revenue from converting other land use types to forestry use under the constraints that the forestry coverage needs to be increased to a certain level required by the central and provincial governments and local resources for forestation need to be utilized under higher level governments' guidance. As mentioned in the statistical description part, the three main land use types in Zhangjiakou are respectively agricultural land, grassland and forestry land. These three land use types make up more than 90% of the total land in Zhangjiakou. Therefore, the county level governments generally need to allocate these three land use types within each land parcel.

In a representative county i, the revenue of forestation of a county firstly depends on the changes of forestry land, which can be denoted as F_i. The amount of agricultural land and grassland in each land parcel can be denoted respectively as A_i and G_i. Grassland is considered as a method to reserve forestry areas and during 1985 to 2000, the grassland did not vary significantly in its total amount as forestry land and agricultural land. Therefore, I will mainly consider forestry land and agricultural land in the theoretical model. Admittedly the grassland has changed locations during the study period, and I will discuss how grassland will affect the estimation in the discussion part of this paper.

Here I use F_i and A_i to stand for the changes of forestry and agricultural lands in county i.

However, it is very important to make it clear that the county level governments are making their decisions of forestation based on land parcels. The reason is that a county would have different geographic and economic conditions inside the county, so the county level land planners not only need to decide how much land conversion they would have, but also where to carry out the land conversion. In this study, I divide the whole study area into 100 meter by 100 meter land parcels, thus the variability in land characteristics can be captured by these land parcels. For the representative county i, I assume that there are n land parcels in total. I use j as the notation for a representative land parcel. Therefore, F_{ij} stands for the change of forestry land in the jth land parcel in county i. Therefore, in county i the total forestry change F_i is actually$\sum_j Fij$, and the total agricultural change A_i is$\sum_j Aij$.

Also, I use F_{0i} and A_{0i} to stand for the forestry area in county i before the Three North Project. Both F_{0i} and A_{0i} can be regarded as parameters for county i.

The revenue generated in the forestation process also depends on the prices of agricultural and forestry products. Therefore, I let P_f stands for the price of forestry product, and P_a stand for the price of agricultural products.

When considering the revenue of choosing a land type between agricultural land and forestry land, the costs have to be included since higher cost will lower the final net revenue level. Here costs incorporate both costs from construction and from maintenance. To distinguish between these two land types, I use C_{fj} to stands for the cost associated with forestry lands in the jth parcel in county i and C_{aj} for the costs of agricultural lands. The total cost of the change in forestry land is $\sum_j Cfi$, and the total cost of the change in agricultural land is $\sum_j Cai$.

Moreover, new forestry areas, which can provide ecological benefits, can also lead to positive externality. Externality is one concept from neo-classic economics (Sidgwick, 1887; Marshall, 1890). Externality can be specified as positive or negative. Forestry land and green space are examples that can lead to a positive externality (Pigou, 1920). In this Zhangjiakou study, we can expect positive externality in the forestation process, since the new constructed trees can reduce the risk of sandstorm, enhance the local ecological system and improve the soil quality, which are the primary concerns of the Three North planners. Given that county-level governments are responsible for their own forestation work, they naturally hope to make the positive ecological externality internal to themselves, instead of sharing it with its neighbor counties. To consider how the county-level governments' concern about externality would affect their locating strategies of the new forestry lands, I use E in my theoretical model to represent the positive externality.

Finally, as I mentioned in the literature review chapter of this thesis, the county level governments can get some political and economic benefits if they can stand out from their colleagues in the forestation process. In other words, choosing forestry land over land types may yield higher political benefits for the county level governments. Therefore, the political benefits should also be considered in the county level governments' revenue function. Therefore, I use B to stands for the non-ecological benefits of the county level governments.

Given these notations, the revenue function of a county i can be written as:

$$R_i\ (F_{0i} + \sum_j Fij,\ A_{0i} + \sum_j Aij,\ P_a,\ P_f,\ \sum_j Cfi,\ \sum_j Cai,\ E,\ B) \tag{1}$$

Therefore, the county level governments actually face the maximization problem as:

$$\text{Max. } R_i\ (F_{0i} + \sum_j Fij,\ A_{0i} + \sum_j Aij,\ P_a,\ P_f,\ \sum_j Cfi,\ \sum_j Cai,\ E,\ B) \tag{2}$$

Literally, this problem means that the representative county i is working to under the motivation to maximize its revenue of the forestation process. To be more specific, this county is deciding how much forestry area change they should have in each land parcel when they are involved in the Three North Project. This maximization problem is associated with some constraints. Firstly, since Zhangjiakou city is included in the Three North Project, the forestry coverage in each country needs to meet the minimum requirements set up by the central and provincial level governments. This constraint can be written as:

$$(F_{0i} + \sum_j Fij) / T_i \geq M \quad (3)$$

Here T_i stands for the total area of county i.

Also, according to Institute of Geographic Sciences and Natural Resources Research of China, new planted trees should be located near the highway system and water system. Additionally, water accessibility is quite important for forestry increase not only because water is essential for trees' survival and policy requirements, but also because Zhangjiakou faces a quite scarce water supply. According to the Zhangjiakou City Government (2011), the annual rainfall amount in Zhangjiakou is 330 to 400 mm per year. Zhangjiakou city is a semi-arid area. Accessible water per capita is only 399 m^3, less than 1/5 of the national average level of accessible water per capita. Therefore, accessibility to water is an important factor for both forestry and agricultural lands. The transportation system is important for forestry and agricultural land, since land parcels nearer to transportation systems are more convenient to be taken care of. Therefore, the distribution of forestry and agricultural land should be within some distances to the nearest water body and highway system. These two constraints can be formulated as:

$$D_1 (F_{ij}) \leq H_1 \quad \text{for } \forall\, j \in n \quad (4)$$

$$D_2 (F_{ij}) \leq H_2 \quad \text{for } \forall\, j \in n \quad (5)$$

where D_1 stands for the distance from the land parcel to the nearest highway system, and D_2 stands for the distance from the land parcel to the nearest water body. H_1 and H_2 are the maximum acceptable lengths from land parcels to the nearest highway or water body.

Finally, the total area allocated to different land uses within a county should be less than the total area of this county. This constraint can be formulated as:

$$F_{0i} + \sum_j Fij + A_{0i} + \sum_j Aij \leq T_i \quad (6)$$

Therefore, for a county i, the forestation problem can be formulated as a maximization problem as:

$$\text{Max. } R_i\ (F_{0i} + \textstyle\sum_j Fij,\ A_{0i} + \sum_j Aij,\ P_a,\ P_f,\ \sum_j Cfi,\ \sum_j Cai,\ E,\ B) \qquad (7)$$

$$\text{s.t. } (F_{0i} + \textstyle\sum_j Fij) / T_i \geq M \qquad (8)$$

$$D_1\ (F_{ij}) \leq H_1 \quad \text{for } \forall\, j \in n \qquad (9)$$

$$D_2\ (F_{ij}) \leq H_2 \quad \text{for } \forall\, j \in n \qquad (10)$$

$$F_{0i} + \textstyle\sum_j Fij + A_{0i} + \sum_j Aij \leq T_i \qquad (11)$$

To solve this maximization problem, the Lagrangian function for county i can be written as:

$$L_i\ (\textstyle\sum_j Fij, \sum_j Aij, \lambda_1, \lambda_2, \lambda_3) = R_i\ (F_{0i} + \sum_j Fij,\ A_{0i} + \sum_j Aij,\ P_a,\ P_f,\ \sum_j Cfi,\ \sum_j Cai,\ E,\ B) - \lambda_1 (F_{0i} + \sum_j Fij - MT_i) + \lambda_2\ [D_1\ (F_{ij}) - H_1] + \lambda_3\ [D_2\ (F_{ij}) - H_2] + \lambda_4\ [F_{0i} + \sum_j Fij + A_{0i} + \sum_j Aij - T_i] \qquad (12)$$

Assuming that I need to find the optimal levels for each F_{ij} and A_{ij}. The first order condition to maximize this function is:

$$R_F'(F_{0i} + \textstyle\sum_{n\neq j} Fin + F_{ij}^*,\ A_{0i} + \sum_j Aij,\ P_a,\ P_f,\ \sum_j Cfi,\ \sum_j Cai,\ E,\ B) + \lambda_1 + \lambda_2\ D_{1F}'\ (F_{ij}^*) + \lambda_3 D_{2F}'\ F_{ij}^*) + \lambda_4 = 0 \qquad (13)$$

$$R_A'((F_{0i} + \textstyle\sum_j Fij,\ A_{0i} + \sum_{n\neq j} Ain + A_{ij}^*,\ P_a,\ P_f,\ \sum_j Cfi,\ \sum_j Cai,\ E,\ B) + \lambda_4 = 0 \qquad (14)$$

$$\lambda_1, \lambda_2, \lambda_3, \lambda_4 \geq 0 \qquad (15)$$

$$F_{0i} + \textstyle\sum_{n\neq j} Fin + F_{ij}^* - MT_i \geq 0 \qquad (16)$$

$$D_1\ (F_{ij}^*) \leq H_1 \quad \text{for } \forall\, j \in n \qquad (17)$$

$$D_2\ (F_{ij}^*) \leq H_2 \quad \text{for } \forall\, j \in n \qquad (18)$$

$$F_{0i} + \textstyle\sum_{n\neq j} Fin + F_{ij}^* + A_{0i} + \sum_{n\neq j} Ain + A_{ij}^* \leq T_i \qquad (19)$$

To simplify this problem, a reduced form of the maximization problem can be written as:

$$\text{Solution } (F_{ij}^*, A_{ij}^*) = f\ (\alpha_1 P_a, \alpha_2 P_f, \alpha_3\ C_{fj}, \alpha_4 C_{aj}, \alpha_5\ E, \alpha_6\ B, \alpha_7 D_1, \alpha_8 D_2) \qquad (20)$$

In this simplified model, to maximize county i's revenue, the optimal levels for F_{ij}^* and A_{ij}^* are determined jointly by price factors, opportunity cost, possible positive externality, non-ecological benefits and accessibilities to transportation and water systems. In short, the county level governments are responsible of deciding which land parcels are to be included in the forestation process, and how many trees should be planted in these land parcels. Moreover, land parcels with different physical characteristics would have different agricultural and forestry values for the county they belong to. For a specific land parcel, if the parcel value from forestry use is larger than the parcel value from agricultural use, then this parcel will be chosen by the county level government to be included in the forestation process.

This above decision process by the county level governments can be represented graphically as in Figure 7.

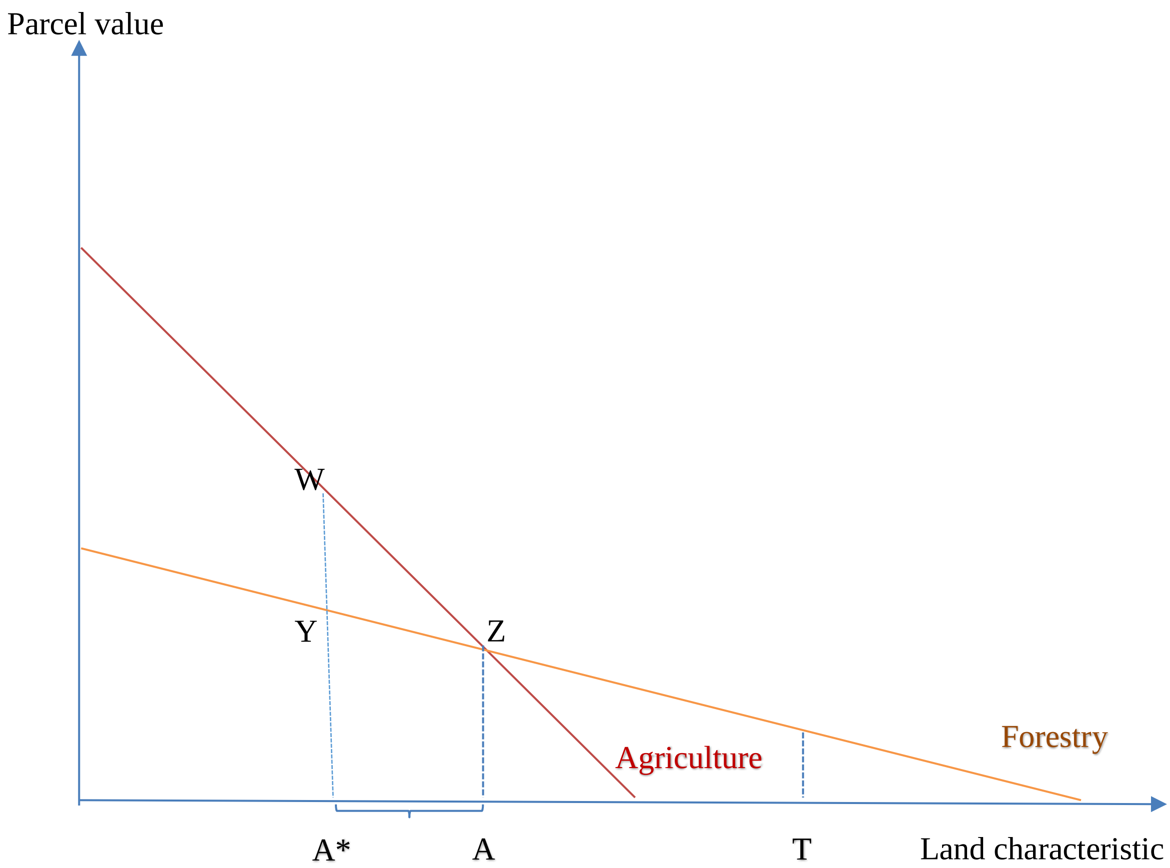


Figure 7. Land characteristics, parcel values and the forestation process

As it can be seen in Figure 7, T is used to stand for the total area in a county. Here I have the relative value curves for both forestry land and agricultural land. These relative value curves are functions of a set of land characteristics, which means that different land characteristics would make land parcels have different relative values in agricultural use and forestry use. In Figure 7 I pick up a representative land characteristic to simplify my analysis. In this simplified model, I assume that both agricultural value and forestry value would decrease when this representative land characteristic increases. However, when we consider the commonly recognized land use factors, it is still possible to have positive slopes for agricultural value curve and forestry value curve.

For a specific land parcel, if its relative value in agricultural use is higher than the its relative value in forestry use, then this land parcel would be assigned with agricultural use. To the contrary, if this parcel's relative value in forestry use is higher, this land parcel will be assigned with forestry use. In Figure 7, A is the land in agricultural use before the Three North Project, and it is determined as the intersection point of the relative value curves.

After the Three North Project, some of the agricultural lands in previous time period would be converted into forestry lands, meaning that we now have A^* in agricultural use, and A^* is smaller than A. The total area converted into forestry can be denoted by the triangle ΔWYZ.

If each county is required to have a certain forestry coverage, then the above model means that in those counties that has less forestry area before the Three North Project, there would be more land conversion than in counties with more forestry area before the project. This is because that in some counties, the land characteristics might not be fully utilized to forestry lands, or the land characteristics in these counties are not ideal for forestry development. These counties have to construct more forestry lands in order to catch up with other counties as for forestry coverage. Therefore in these counties the slope for the forestry relative value curve should be flatter. Therefore, when the agricultural area decreases from A to A*, the triangle $\Delta WY'Z$ should be larger than ΔWYZ, as it can be seen in Figure 8.

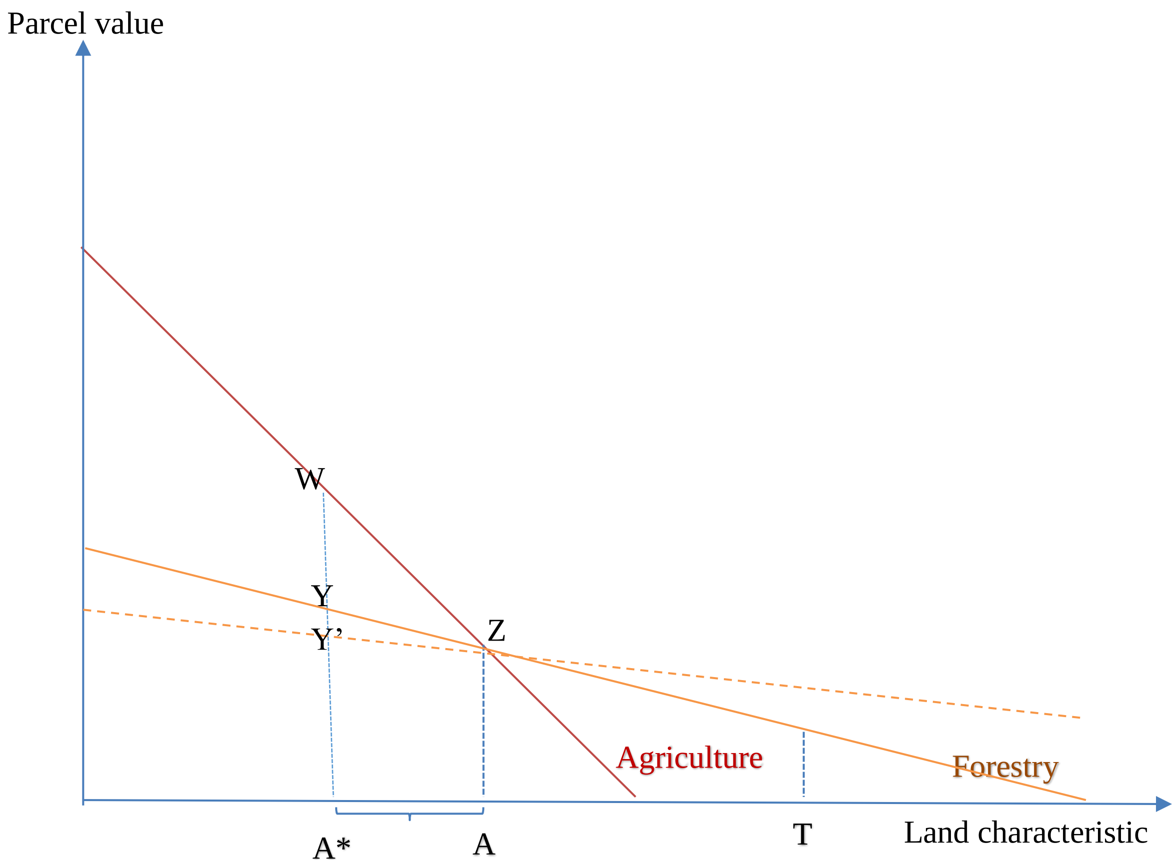


Figure 8. Flatter forestry relative curve and the new total forestation area

Therefore, it can be seen from Figure 7 and Figure 8 that various land characteristics would affect land parcels' relative values in agricultural use and forestry use. Therefore, the county level governments actually have a set of land parcels with various land characteristics. The land parcels with higher forestry value than agricultural value would be included in the forestation project. Therefore, now I will then discuss how these land characteristics affect the relative values, and eventually affect the locations and amounts of land converted.

When we try to consider the cost of construction and maintenance of the agricultural and forestry lands, we have to consider local climate and geographical factors. As mentioned in part 3 of this thesis, Zhangjiakou city has a higher level of variation in its elevation level. Most of the high elevation areas in Zhangjiakou belong to Mongolian Plateau, and Bashang area is the southern edge of Mongolian Plateau, which is featured by a low rainfall level of

200mm per year (Zhou et al., 2012). Generally high elevation areas in Zhangjiakou, mainly in Bashang, are not ideal for agricultural production. In the low elevation areas in Zhangjiakou, there are several famous basins, including Yangyuan Basin, Huaizhuo Basin and Weisian Basin. To the contrary of the aridness of the high elevation areas, several rivers run across these basins, making the soil quite fertile humid for forests and agricultural production to occur. Considering the relatively low agricultural potential of high elevation areas in Zhangjiakou, locating agricultural areas in low elevation areas would guarantee the agricultural annual yields and the governments' income. However, the county-level governments would have less incentive to locate new forests in low elevation areas since no annual income would be generated from the young trees even though the low elevation areas may be more suitable for the trees' growth or survival. Therefore, planting new trees in high elevation areas and agricultural products in low elevation areas may generate higher revenue for the county-level governments. In other words, in low elevation areas, agricultural lands can be relatively more valuable than forestry land, meaning that the relative parcel value in agricultural use Va is higher than the relative parcel value in forestry use Vf. Also, I have the hypothesis that $\frac{\partial F*}{\partial elevation} > 0$.

Both the agricultural lands and forestry lands should be located near transportation. The accessibility to the transportation system affects both the land costs and the prices of agricultural and forestry products. Firstly, both of the agricultural products and new planted trees need human and mechanical maintenance. Agricultural lands should be given easiest accessibility to the transportation system since agricultural lands need to be taken care of carefully in order to guarantee a certain annual yield level. Secondly, locating agricultural land near the transportation system would make it easier to transport agricultural products to their markets—the short travelling time from the origin to the market would guarantee the quality of the agricultural products, giving the products better prices at the market. However, as for forestry land, the central or provincial governments do not carry out a guideline or supervision system for maintenance and no annual income can be expected from the new planted trees. Thus local governments will pay less attention on maintenance of the new trees than the agricultural products. Consequently, agricultural land is likely to be developed near the transportation system. Meanwhile, forestry land has to give its way to agricultural land, and get developed away from the transportation system. In short, the for the land parcels near the transportation system, we can have the relationship that $Va > Vf$. Moreover, I make the prediction that as the distance from land parcels to the nearest highway increases, the forestry coverage within these land parcels will increase as well, meaning that $\frac{\partial F*}{\partial D1} > 0$.

Meanwhile, locating forestry lands and agricultural lands near the water bodies would save the costs of construction and maintenance. Given the fact that Zhangjiakou has a low annual rainfall level, the growth of agricultural products and new planted trees have to rely on local water resources. Therefore, to guarantee the agricultural yield level and the survival of new trees, both the agricultural lands and forestry lands need to be located near local water bodies. However, agricultural lands should be more sensitive to the location of water bodies due to the fact that local governments have higher incentive to maintain agricultural lands than forestry lands because they can get steady annual income from the agricultural productions. Consequently, both agricultural and forestry lands would be located near the water bodies, but agricultural lands would own better water accessibility than forestry lands. As the distance to the nearest water body increases, both the agricultural value and forestry value would decrease. Therefore, I make the prediction that as the distance from land parcels to the nearest water body increases, the forestry coverage within these land parcels will decrease, meaning that $\frac{\partial F*}{\partial D2} < 0$

Even though both forestry and agricultural lands are immobile, forestry lands are more likely to generate positive ecological externality. Therefore, if the county-level governments hope to avoid positive externality that can be enjoyed by its neighbors, they may want to locate the new forests away from the county borders. In other words, for land parcels away from the county borders, land parcels' forestry values would be larger than the agricultural values, which means that $Vf > Va$. To the contrary, for land parcels near the county borders, agricultural values would be higher than forestry values. Therefore, I can make the prediction that the longer the distance from a land parcel to the county border is, the higher forestry coverage level this land parcel will have.

Additionally, when we consider the benefits of the forestation process, it is obvious that not only ecological benefits are involved. Since the construction of forestry lands are required by the central and provincial governments, county level governments are more likely to gain political benefits if they can meet or even exceeds the minimum requirements for forestry construction. Therefore the construction of forestry lands is more likely to give non-ecological benefits for county level governments. For agricultural land, similar political benefits do not exist since there are no policies or national projects encouraging the construction and expansion of agricultural land. If the county level governments do have the incentive to compete with each other and response positively to their neighbor counties' forestry increase, then the increase of forestry coverage in land parcels would demonstrate positive spatial autocorrelation. Therefore, in the empirical study part, I will try to find evidence of spatial autocorrelation, and try to distinguish the spatial autocorrelation from governmental interaction and from the continuity of other variables in this study.

Besides the above land characteristics that can be clearly associated with equation (20) in this chapter, I also consider urbanization and slope in my empirical study, since these are the commonly used factors in land use change studies. In China, urbanization generally encourages the growth of township and some small industries (Liu et al., 2003). At the same time, urbanization level is generally negatively related with agricultural or forestry coverage

(Xiao et al., 2006). Therefore, the construction of forestry or agricultural lands would lead to a pretty high cost and low net revenue in already urbanized areas. Due to this reason, I assume that the forestation process is more likely to take place in under urbanized areas, meaning that forestry coverage will be positively related with the distance to the nearest urban site.

In summary, a land parcel is likely to be converted into forestry use if this land parcel is under urbanized, far away from county borders and the transportation system, has high elevation, and has easy access to water system. Additionally, the distribution of new constructed forestry areas should demonstrate positive spatial autocorrelation since county level governments need to exceed neighbor counties in order to stand out and obtain political benefits from the central or provincial governments.

I will use an empirical study to test my assumptions above. Before the empirical study, I will explain and describe the independent variables in the statistical description part.

4.2 DESCRIPTION OF INDEPENDENT VARIABLES

(1) Accessibility to highway and water systems

The distribution of highway and water systems can be shown in Figure 9.

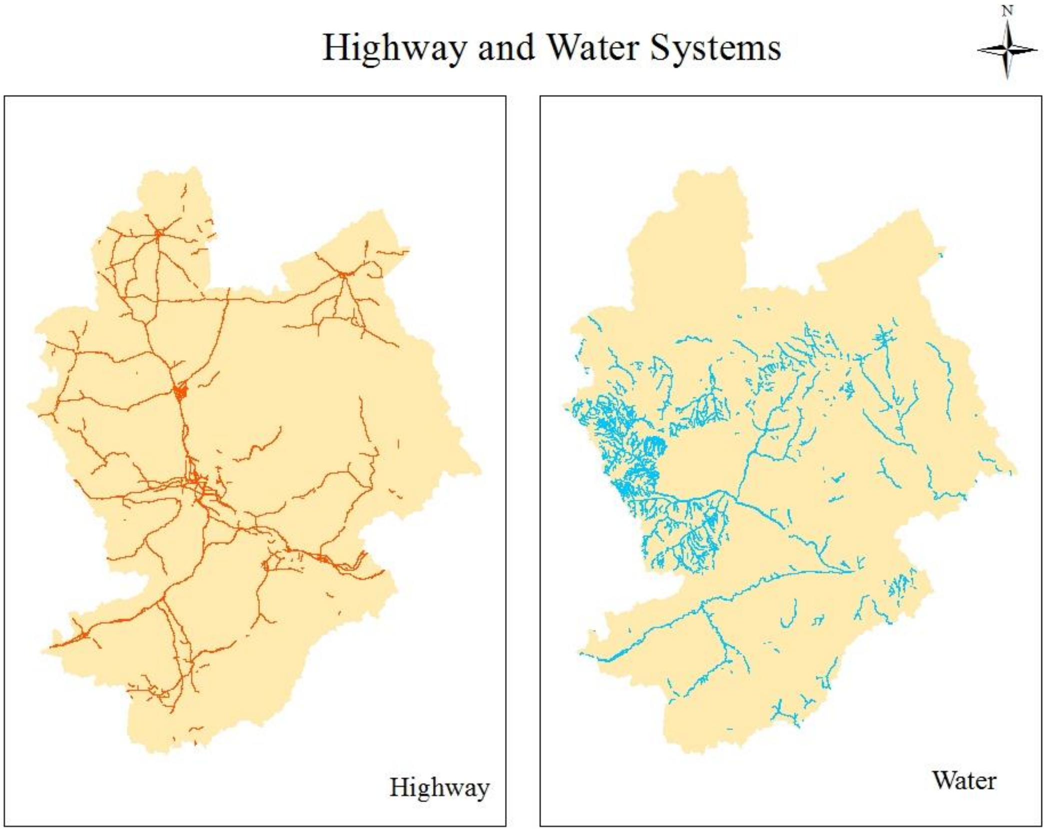


Figure 9. Highway and water systems in Zhangjiakou

As it can be seen from this figure, main water bodies are all in the southern part of this city, which is also called Baxia area. For the upper part of the city, known as Bashang, there are no main water systems. With the distribution of water systems, we can see that Bashang area suffers more aridness than Baxia area.

The highway system is more evenly distributed across the whole Zhangjiakou city. Compared with other parts of Zhangjiakou city, the northeastern part of this city does not have as dense highway systems. However, generally speaking, the highway system spreads out across the whole city.

When we look at the land use distribution map in Figure 3, we can see there is a formation of continuous forestry lands in the middle area of Zhangjiakou. However, as it can be seen in Figure 9, highways do not exist in this area. This may lead to the fact that the distance to the highway system would positively contribute to increase of forestry coverage in land parcels. Also it can be seen in Figure 9 that Bashang area, especially Kangbao and Guyuan, is relatively dry. Given the fact that most of the forestry increase occurs outside these two counties, the land parcels near the water system are more likely to have forestry increase. The correlation of the change in forestry coverage with the distance to highway is 0.1699 and the correlation of the change in forestry coverage with the distance to water is -0.0736. These correlations suggest the pattern that new forestry lands are away from the highway system but near to the water system.

(2) Distance to the county borders

Few previous studies have chosen the distance to county border as one driving factor for land use changes. However, including this variable in Zhangjiakou study is necessary since I assume that county-level governments have the incentive to make the positive forestry externality internal, thus the change in forestry coverage will respond negatively to the increase of distance to the county borders.

Since the sample of this study contains land parcels within 2 kilometers buffers along the county borders, distances from the county borders to land parcels are positive values that are within 0 to 2000 meters.

Even though obvious relationship between the forestry coverage change and existence of county borders cannot be observed from Figure 3 and Figure 7, we can still use the correlation between these two variables to explore how they are related. With the sample of the study, the correlation of the change in forestry coverage with the distance to the county border is 0.2115, meaning that the new forestry lands are away from the county borders.

(3) Urbanization level

Urbanization rate in Zhangjiakou remains at 2% from 1985 to 2000. According to Hebei Statistical Yearbook in 2006, the urban proportions for different counties can be shown in

Table 4 and Figure 10.

Table.4. Urbanization levels in the counties in Zhangjiakou

	Urbanization Level	**Urban Population**	**Rural Population**
Xuanhua	0.0917	14797	146548
Zhangbei	0.0544	10968	190465
Kangbao	0.0636	9389	138231
Guyuan	0.0592	7152	113630
Shangyi	0.0841	9300	101319
Wei	0.1109	22524	180560
Yangyuan	0.1308	17004	112951
Huaian	0.1014	12522	110951
Wanquan	0.0917	10358	102654
Huailai	0.1019	17009	149975
Zhuolu	0.1299	22292	149325
Chicheng	0.0908	11275	112945
Chongli	0.1462	9850	57544

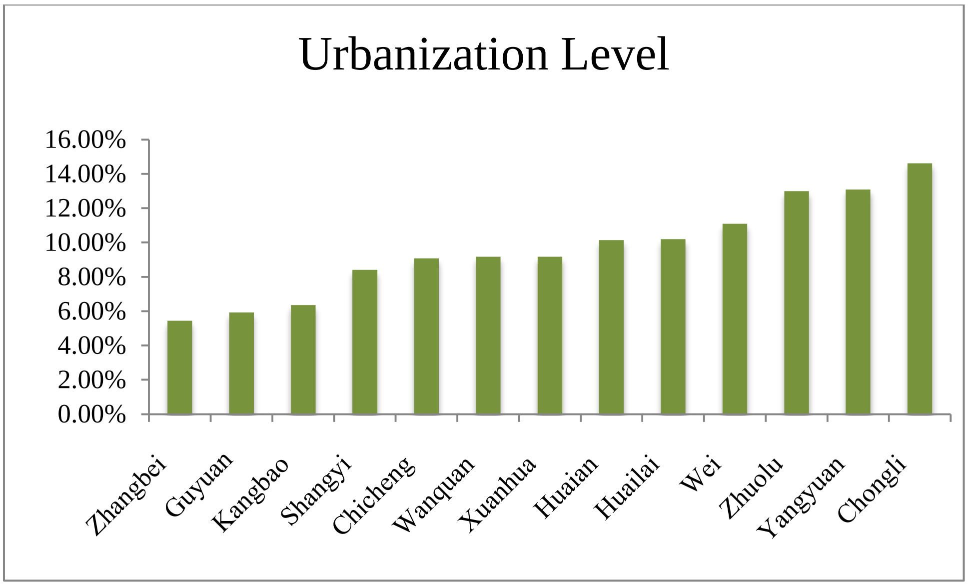


Figure 10. Urbanization levels in the counties in Zhangjiakou

In Zhangjiakou city, Chongli county, even though has the lowest population density, the urbanization level is the highest among all the thirteen counties. The four counties from Bashang area have the lowest urbanization levels. Urbanization levels in Bashang are generally smaller than 8.5%, which indicates that Bashang is less urbanized than Baxia area.

It can be seen from Figure 3 that the main urbanized areas in Zhangjiakou are in Xuanhua County, which is to the southern part of Yin Mountain, where the main forestry increase happens. In Kangbao, Guyuan, Shangyi and Zhangbei, even though large urbanized areas cannot be observed, the small urbanized sites spread across these four counties. This pattern is quite similar to the distribution of new forestry sites in these four counties.

The above population data is only available based on county-level. Since this study uses land parcels to investigate the driving factors and mechanism of land use changes, data based on county-level would not be suitable to stand for urbanization information in every land parcel. Therefore, to more accurately capture the urbanization information within each land parcel, I measured the distance from each land parcel to the nearest urban site at the beginning of our study period. I use the distance from each land parcel to the nearest urban site as the indicator to represent the accessibility to urbanized areas.

(4) Elevation and slope

This study extracts elevation map from digital elevation model (DEM) file from Prof. Yueqing Xu of China Agricultural University. The DEM file is a raster file constituted by 100*100m land parcels. For Zhangjiakou city, high elevation areas are in Bashang area, with the average elevation of 1400m. Compared with Bashang area, Baxia area has a lower elevation level of 500m to 1000m.

When we compare Figure 3 with Figure 11, it can be discovered easily that the forestry changes are more likely to occur where the elevation has greater variability. Especially in Chongli, Chicheng, Wei and Zhuolu, the distribution of new forestry lands coincides considerably with the distribution of the mountainous areas.

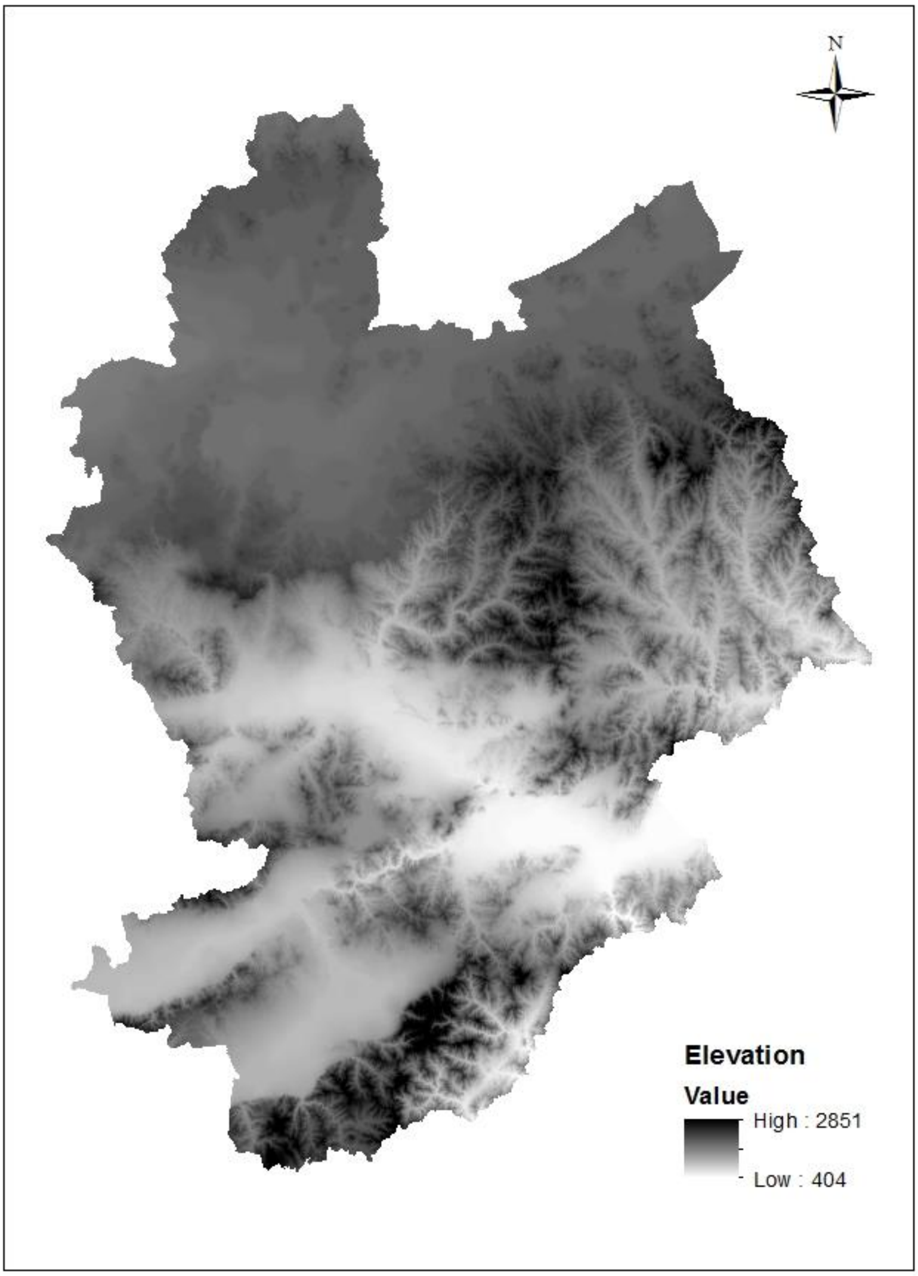


Figure 11. Elevation map of Zhangjiakou

A brief introduction of the dependent variable and independent variables is given in Table 5.

Table.5. Dependent variables and potential independent variables

Dependent variable	**Variable Description**
Forestry Changes	Net change in forestry percentage in each 100m* 100m land parcel
Independent variables	
Distance to county border	Distance from each land parcel to the nearest county border
Accessibility to water	Distance from each land parcel to the nearest water body
Accessibility to highway	Distance from each land parcel to the nearest highway
Elevation	Elevation for each land parcel
Slope	Average slope for each land parcel
Distance to the nearest urban site	Distance from each land parcel to the nearest urban site

The statistical summary of both the dependent variable and potential independent variables can be summarized as below:

Table 6. Summary of the dependent variable and potential independent variables

Variable	Unit	Mean	Median	Range Lowest	Highest
Wy	NA	1391	0	-10000	10000
WyBorder	NA	76.94	0	-10000	10000
Forestry changes	square meter	1391	0	-10000	10000
Distance to county borders	meter	967	951	0.00037	2000
Accessibility to highway	meter	7060	5855	0	24660
Accessibility to water	meter	4515	2948	0	26150
Elevation	meter	1295	1382	499	2853
Slope	degree	7.86	6.07	0	61.72
Distance to urbanized area	meter	2390	1721	0	9999

After the introduction of the independent variables, this paper gives a regression analysis, aiming to find out the driving factors and the resource of spatial autocorrelation for land use changes in Zhangjiakou.

CHAPTER 5

MODEL SPECIFICATION

Firstly, this paper uses OLS regression to investigate the general relationship between land use changes, especially the forestry changes, and the driving factors in Zhangjiakou city. This study divides the whole study area into 100×100 meter^2 land parcels. Therefore, it will be quite time consuming and inefficient if I include all the land parcels in Zhangjiakou into the empirical study. To simplify this study, I make a 4-mile buffer along the county borders (2 miles on each side of the borders). Now only 514669 land parcels are included and this strategy would considerably speed up the regression process. The buffer along the county borders and the included land parcels can be seen in Figure 12.

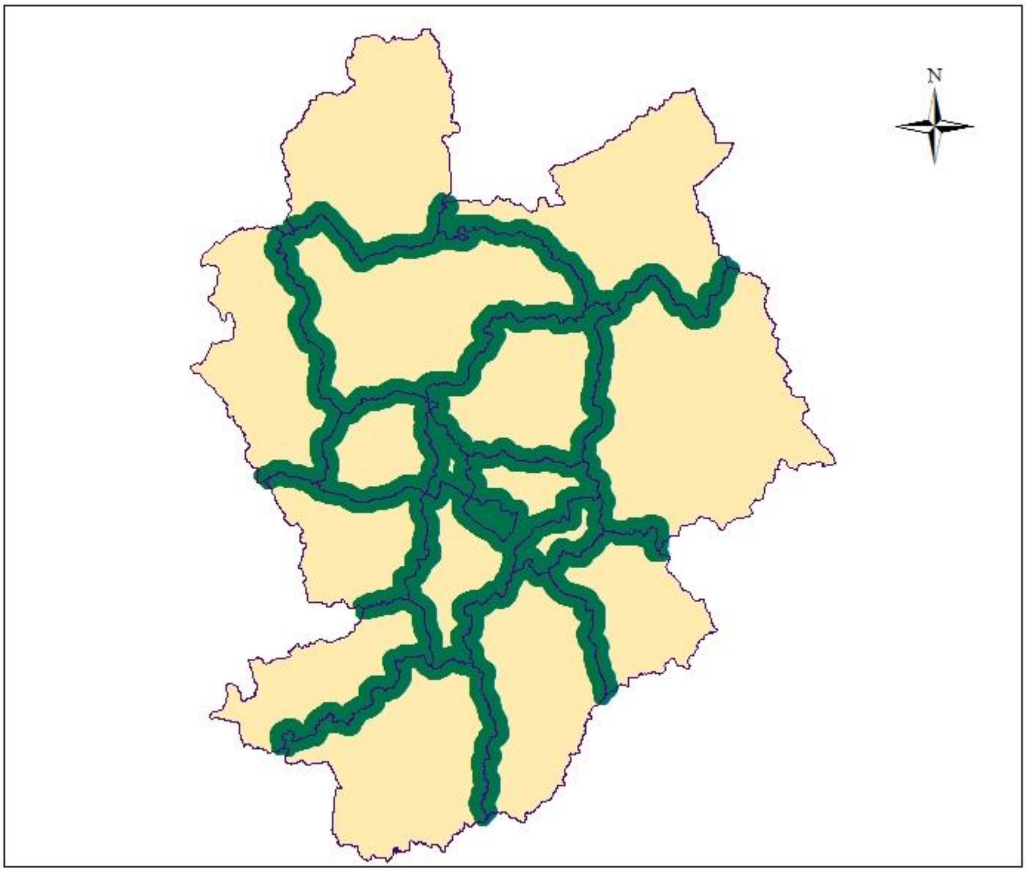


Figure 12. 4-kilometer buffer area along the county borders

To show that the sampling strategy of taking land parcels along the county borders would not cause any significant bias in my model, I compare the statistical summaries of the land characteristics for both parcels in the sample and all the parcels in Zhangjiakou city. The comparison results are shown in Table 7.

Table 7. Statistical comparison of parcels in the sample and the population

	Unit	**Mean**	
Variable		Sample	Population
Accessibility to highway	meter	7060	6578
Accessibility to water	meter	4515	8143
Elevation	meter	1295	1262
Slope	degree	7.86	6.33
Distance to urbanized area	meter	2390	2410

From Table 7, we can see that for most of the land characteristics considered in my model, the sample mean and population mean are quite similar, meaning that the land parcels in the buffer area along the border are not systematically different from other parcels in the Zhangjiakou city. The only exception is the accessibility to water. For the sample, the mean of distance to water is 4515 meters, and the population mean is 8143. Even though the population mean and sample mean are not similar for this variable, the sample I have selected is quite representative of the population because of two reasons. First of all, when we look at Figure 7 for the water system and Figure 11 for the county border system, it can be discovered that none of the 13 counties have intentionally used the rivers or other water bodies as their borders and the water system is more dense in southern part of Zhangjiakou, but the distribution of the water system is not coincide with counties borders. Secondly, when we look at Figure 9, it can be discovered that two of the counties, Guyuan and Kangbao, being in the most northern part of Zhangjiakou and away from the county borders, do not have a water system in their territories. Therefore, when we include these two counties in the population, the mean of the distance to water would be considerably increased. However, for other counties in Zhangjiakou, they all have water system within their territories. Actually when these two counties are not considered, the mean value of the distance to water is just 2718.79 for all the other land parcels. Therefore the sample actually can represent the accessibility to water for most of the counties and most of the parcels in Zhangjiakou.

The formation of the county borders in Zhangjiakou can be a complicated historical research question which is beyond this paper's main concentration. For instance, Wanquan, Shangyi and Zhangbei are separated by the Ming Dynasty Great Wall. Even though the principle of defining the county borders is unclear, it can be observed by Figure 9, Figure 11 and Table 7 that counties in Zhangjiakou do not use certain land characteristics to define the county borders. Therefore, the land parcels near the county borders are not considerably different from other parcels in Zhangjiakou city, which means that my sampling strategy will not generate systematic bias.

If we use OLS model to denote the forestry increase and the driving factors in each land parcel, the model can be formulated as below:

$$yi = \alpha nXn + \beta + \mu$$

In this model, yi, the dependent variable, denotes the forestry changes in land parcel i. Xn in this model represents a set of different driven factors of land use conversions. β is the constant factor in this model and μ is the error term of this regression model.

If all the dependent variables are included in this regression model, then this OLS regression can be specified as:

$$
\begin{aligned}
&Forestry\ coverage\ change \\
&\quad = \alpha 1 * distance\ to\ water + \alpha 2 * distance\ to\ highway + \alpha 3 * economic\ ranking + \alpha 4 \\
&\quad * distance\ to\ urban\ site + \alpha 5 * elevation + \alpha 6 * distance\ to\ county\ border + \alpha 7 \\
&\quad * slope + \beta + \mu
\end{aligned}
$$

Considering that counties may have a competition for forestry construction, spatial autocorrelation may exist across different land parcels. Therefore, a spatial lag term is included in this model as well. Then this model can be modified as:

$$y = \beta + \alpha n X n + \rho W y$$

In this spatial lag model, W stands for the spatial weight matrix. If the county governments are under the peer pressure to construct more forests, then there may be a positive spatial autocorrelation across different counties, which can be denoted by a positive ρ value.

However, even though the empirical test can reveal a positive ρ value, it is still difficult to conclude that the positive spatial autocorrelation is resulted from governmental competition. In order to more precisely capture the evidence for governmental interaction, I pick out the land parcels that have nearest neighbor land parcels across the county borders. These land parcels, even though they do not have county borders within themselves, are generally within short distances to the borders. These land parcels and their nearest neighbors are generally adjacent to the border or within 100 meters of the border. In order to simplify the writing, I call these land parcels "border parcels" since these parcels are probably influenced by spatial autocorrelation both within and across the country borders. All the border parcels are denoted by integer numbers that represent each county border. Therefore, the spatial model can be revised as:

$$y = \beta + \alpha n X n + \rho W y + \gamma * W y * Border$$

In this spatial model, the term $\gamma * Wy * Border$ denotes the spatial lag along the county borders. If county-level governments are competing against each other in forestry construction, it would be reasonable to assume that the spatial lag within counties would be different from spatial lag across counties. If so, γ in this spatial regression would be positively significant.

Based on the above model specification, I run the land use and other related data, and the results of the regressions are summarized in Chapter 6.

CHAPTER 6

RESULTS

In this study, I use Geoda for OLS and spatial lag model regressions. Then I use R for the revised spatial lag regression. Firstly, using the forestry coverage changes in each land parcel as the dependent variable, the result of OLS regression are reported below.

Table 8. OLS results for forestry coverage changes in each land parcel

Variables:	Coefficients:
Constant	-1196.49*** (-55.578)
Distance to county border	0.07*** (7.452)
Accessibility to highway	0.05*** (42.94)
Accessibility to water	-0.10*** (-86.15)
Elevation	2.14*** (122.268)
Distance to urbanized area	-0.04*** (-13.15)
Slope	-5.72*** (-7.536)
Adjusted R-squared	0.063
N	514669

Note: t-values are shown in parentheses
* = significant at 10%, **=significant at 5%, *** = significant at 1%

To detect spatial autocorrelation in this OLS regression, using a distance-based weight matrix, LM test results and Moran's I for the dependent variable are reported in Table 9 and

Figure 13.

Table 9. LM tests results

Test	Value
Lagrange Multiplier (lag)	764777.56 (0.000)
Robust LM (lag)	74.20 (0.000)
Lagrange Multiplier (error)	764712.39 (0.000)
Robust LM (error)	9.02 (0.002)

Note: P-values are shown in parentheses

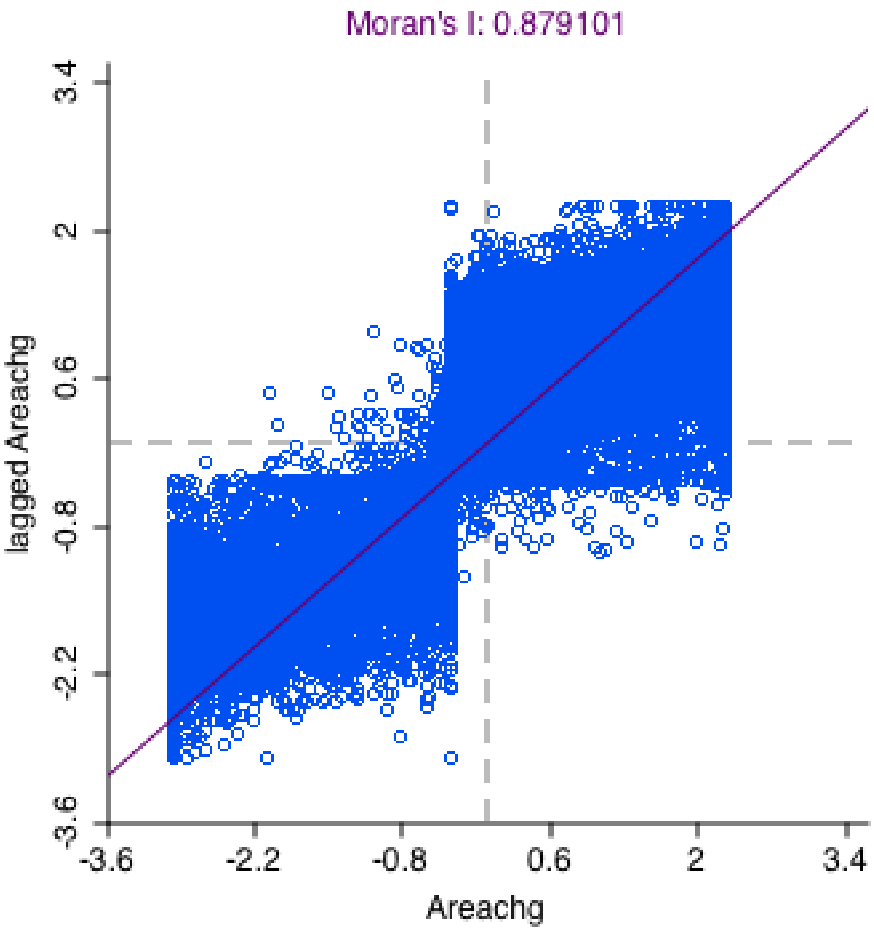


Figure 13. Moran's I for the dependent variable (forestry coverage changes)

It can be seen from Table 8 that both the LM-Lag statistic and LM-Error statistic are significant at 1% significance level. However, the LM-Error$_{robust}$ statistic is not significant, while the LM-lag$_{robust}$ statistic is still siginificant at 1%. Therefore, the results of LM tests reveal that spatial lag model (SLM) is the appropriate specification.

It can also be seen from Figure 13 that for the independent variable, the observations and the lagged value of observations tend to cluster in the upper right quadrant and lower left quadrant. Since we use the upper right quadrant to stand for high-high clusters, and we use the lower left quadrant to stand for low-low clusters, it can be shown that most of the points in this Moran’s I scatterplot belongs to either high-high clusters or low-low clusters. The reason for this pattern is probably that the forestation areas and deforestation areas are deliberately separated because of the effect of Three North Project. It means that governments may choose some particular areas for forestry construction, and also sacrifice some areas’ forestry coverage. Also, since the land use change value within each land parcel has the maximum value of 10,000 and the minimum value of -10,000, the points in my Moran’s I scatterplot tend to be confined into upper and lower boundary values.

The results of spatial lag model are reported in Table 10.

Table 10. Spatial lag regression and OLS regression results

Variables: Coefficients:	Spatial Lag	OLS
Constant	-63.83***	-1196.49 ***
	(-9.085)	(-55.578)
Distance to county border	0.004	0.07***
	(1.246)	(7.452)
Accessibility to highway	0.003***	0.05***
	(6.770)	(42.94)
Accessibility to water	-0.005***	-0.10***
	(-13.949)	(-86.15)
Elevation	0.113***	2.14***
	(19.667)	(122.268)
Distance to urbanized area	-0.002**	-0.04***
	(-2.095)	(-13.15)
Slope	-0.188	-5.72***
	(-0.760)	(-7.536)
Rho	0.947***	NA
	(2145.58)	
N	514669	514669

Note: t-values are shown in parentheses
* = significant at 10%, **=significant at 5%, *** = significant at 1%

According to the results of spatial lag model, Rho, the spatial lag parameter, is positive and significant, indicating that positive spatial autocorrelation does exist for forestry increases in Zhangjiakou. This positive spatial lag parameter indicates that a land parcel's change in the forestry coverage is positively related to its neighbors' changes in their forestry coverage.

When considering the spatial lag term, most of the other independent variables, except the distance to county border, are still significant. The reduction in significance of distance to county border is probably because the spatial lag model has reduced some inflation in independent variables' contribution to changes in forestry coverage. Compared to the OLS results, the spatial lag model coefficient results are all smaller. This confirms the observation that use of coefficients from naïve OLS models may be biased and lead to overstating policy implications and effect sizes where spatial autocorrelation is present.

In order to detect if the spatial autocorrelation within counties is different from spatial autocorrelation across counties, I pick up the border parcels, denote these parcels by using a dummy variable, and finally revise the spatial lag model by adding a term that stands for border parcels' spatial autocorrelation. The results of the revised spatial lag model are presented in Table 11.

Table 11. Comparison of the spatial lag regression and revised version

Variables: Coefficients:	Spatial Lag	Revised Spatial Lag
Constant	-63.83*** (-9.085)	-65.542*** (-9.327)
Distance to county border	0.004 (1.246)	0.006** (2.010)
Accessibility to highway	0.003*** (6.770)	0.003*** (6.819)
Accessibility to water	-0.005*** (-13.949)	-0.005 *** (-13.853)
Elevation	0.113*** (19.667)	0.112*** (19.503)
Distance to urbanized area	-0.002** (-2.095)	-0.002** (-2.107)
Slope	-0.188 (-0.760)	-0.175 (-0.710)
Rho	0.947*** (2145.58)	0.946*** (2138.446)
$\boldsymbol{WyBorder}$	NA	0.085*** (15.279)
N	514669	514669

Note: t-values are shown in parentheses
* = significant at 10%, **=significant at 5%, *** = significant at 1%

Above are the empirical results of the land use change model in Zhangjiakou. Detailed analysis of the above results will be undertaken in the coming chapter of the thesis.

The above regression results suggest the pattern in the distribution of the new forestry lands. To be more specific, in the OLS model, once the distances respectively to the county border and to the highway system increase by 0.07 meters and 0.05 meters, the land parcels' increase of forestry coverage would increase by 1 square meter. This means that the forestry increase would occur away from the highway system and the county borders. Meanwhile, as the distances respectively from the water system and the nearest urban site increase by 0.1 and 0.04, the land parcels' increase of forestry coverage would decrease by 1 square meter, which means that the forestry increase would happy near the water system and urbanized areas. Moreover, land parcels with high elevation but low slope are more likely to have forestry increase. In the spatial lag model and revised spatial lag model, the marginal effects of these variables are similar. The above results suggest the distribution of new forestry land. In Chapter 7 of this paper, I will discuss if the empirical results match my predictions in Chapter 4. If not, I will explain why the empirical results would not support the theoretical predictions.

CHAPTER 7

DISCUSSION AND CONCLUSION

This paper concentrates on the mechanism of land use changes, especially the changes in forestry coverage in Zhangjiakou, Hebei, China. Chapter 1 gives the general background of Zhangjiakou since 1985. This paper takes Zhangjiakou as the study area since it has been included in a national forestry construction program since 1980s. Therefore, Zhangjiakou is a representative example to analyze the mechanism for land use changes in China, since land use changes in China are basically under governments' control, such as national or local policies or projects. Chapter 2 reviews previous literature on land use changes. Chapter 3 describes the study area of this paper. Chapter 4 constructs a land use change model to explain the possible mechanism for land use changes in Zhangjiakou. Some hypotheses are made based on the assumption that county-level governments are aiming at maximizing their revenue when they choose among different land use types. Later on, Chpater 5 specifies the possible empirical models that can possibly support the land use change model in Chapter 4. Based on this model specification and the data from Prof. Yueqing Xu from China Agriculture University, Chapter 6 summarizes the empirical results. This part of the paper is the discussion and conclusion part. In this part, I will demonstrate how the empirical and theoretical works are related. The mechanism for land use changes will be discussed in detail.

This part of the paper will be divided into three parts: firstly, this paper will demonstrate how the land use changes in Zhangjiakou can be attributed to interactions between county-level governments. Secondly, some non-governmental factors for land use changes will also be discussed. Compared with some previous Chinese land use changes literature do not consider governmental factors, this paper tries to see if these non-governmental factors act differently in empirical test when we take into consideration the governmental interactions. Lastly, the overview of land use changes in China will be summarized, and I will summarize some potential problems resulted from forestry construction based all the analysis above.

7.1 GOVERNMENTAL INTERACTIONS AND LAND USE CHANGES

In Chapter 6 of this paper, it can be seen that spatial autocorrelation can always be found significant by LM tests when we run OLS regressions for Zhangjiakou city. Also, the positively significant spatial lag parameter Rho also indicates that land parcels are acting positively with respect to their neighbors' behaviors in forestry construction. However, only a spatial lag model is not enough to prove the behavior of county-level governments, since the spatial lag model, which can reveal the evidence of spatial autocorrelation, can hardly prove the resource of spatial autocorrelation. Therefore, in order to more directly answer my research question, which is whether governmental behaviors will lead to the increase of forestry coverage, I introduce the revised version of spatial lag model in this study.

The revised model, using the interaction of normal spatial lag Wy and the variable that represents border parcels to specify the spatial lag at an inter-county level. Border parcels in this study are defined as the land parcels that have nearest neighbor parcels across the county borders. Therefore, these land parcels receive spatial influence not only from the parcels of their own counties, but also from parcels belong to other counties. In the empirical study, the interaction is positively significant, indicating that spatial autocorrelation across borders is different from the spatial autocorrelation within counties. This is the evidence that county-level governments are interacting with each other for the forestry construction.

Besides the spatial lag model and the revised spatial lag model, we can even discover the evidence of spatial autocorrelation when we compare the increase of forestry coverage by each county.

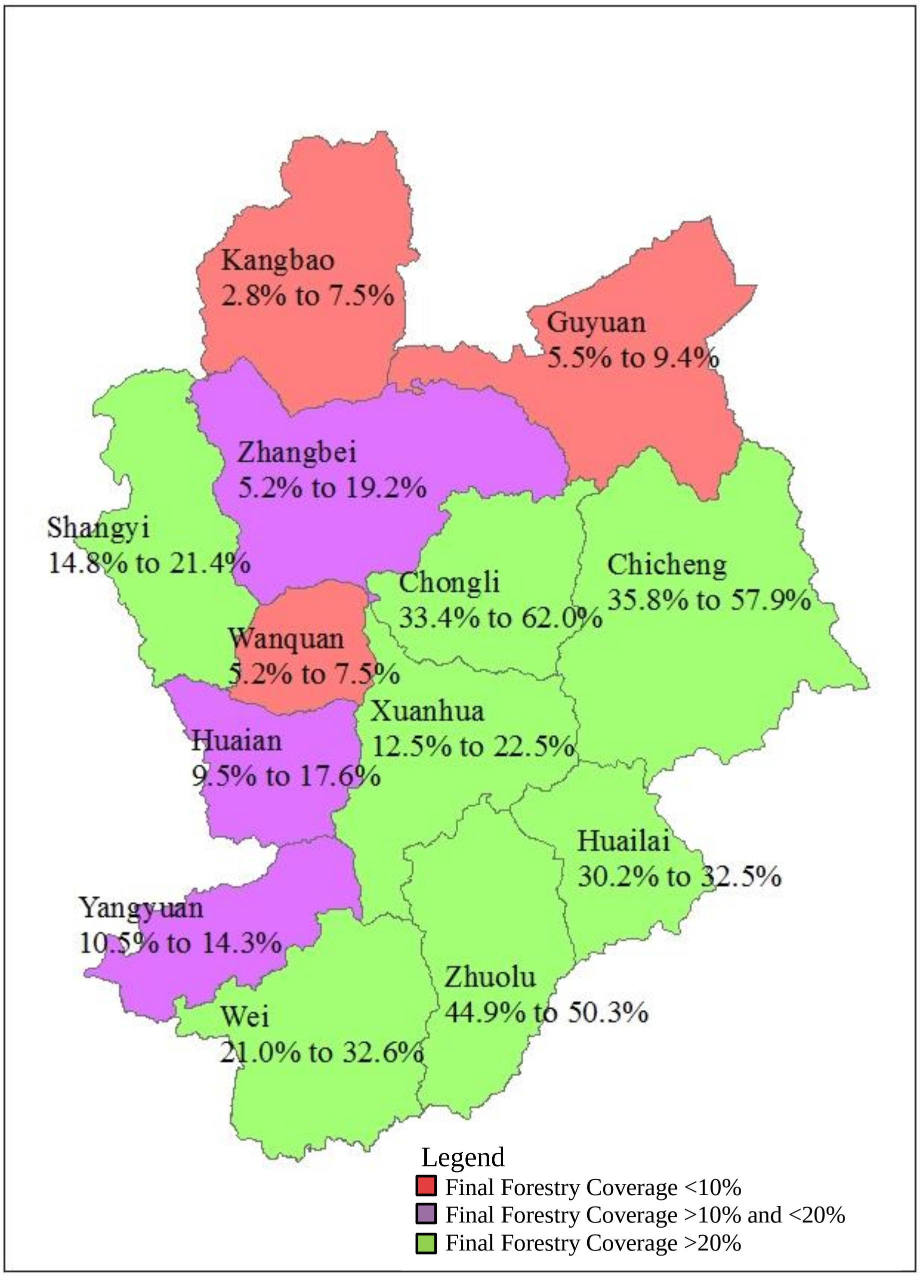


Figure 14. Comparison of the increase of forestry coverage by each county

As it can be seen in Figure 14, Kangbao, Guyuan and Wanquan have the forestry coverage below 10% by the end of 2000. Among these three counties, Kangbao and Guyuan are adjacent in the northern part of Zhangjiakou. According to Hebei Statistical YearBook in 2006, these two counties are the most undeveloped counties in the province (ranking respectively 140th and 139th among all the 140 counties in Hebei Province). Also, as mentioned before, these two counties do not have water bodies inside their territories, making the supply of water to new trees quite difficult. Despite the undesirable economic background and the shortage of water, these two counties respectively tripled and doubled their forestry coverage from 1985 to 2000. Also, when we look at the distribution of new forestry lands in these two counties from Figure 3, we can easily observe that in these two counties the new forestry sites are all quite small and separated from each other.

Shangyi County, Huaian County and Yangyuan County have the richest water supply and the densest transportation system in all the 13 counties in Zhangjiakou. Their economic rankings among the 140 counties in Hebei are respectively 138th, 118th, and 110th according to Hebei Statistical YearBook in 2006. When we look at the changes in forestry coverage, these three counties all have increased their forestry coverage by approximately 5%, and their final forestry coverage by the end of 2000 are all around 20%.

All other counties in Zhangjiakou have the final forestry coverage higher than 20%. By the end of 2000, Chongli has the highest forestry coverage of 62.0%, followed by Chicheng (57.9%) and Zhuolu (50.3%). Most of other counties with high forestry coverage by the end of 2000 are adjacent to Chongli, Zhuolu and Chicheng.

Therefore, as it can be seen in Figure 14, counties with similar economic strength and shorter geographic distance would probably have similar performance in the Three North Project. However, counties with the forestry coverage do not necessarily have the most ideal transportation and water systems to maintain the new forestry lands. Moreover, given that the biggest economic center of Zhangjiakou is currently in Xuanhua County, the high forestry coverage in Xuanhua and neighboring counties may even impede future urban expansion process.

In short, we can discover that counties tend to response positively to neighboring counties' increase in forestry coverage by the revised spatial lag model and the statistical summary of each county. Therefore, county level governments' interaction is an important factor related to forestry spatial autocorrelation in the Three North Project.

To precisely capture the mechanism of land use changes in China, spatial autocorrelation, probably can be specified by different forms, needs to be considered in both theoretical and empirical models. The data of this paper is from Prof. Yueqing Xu in China Agricultural University and Prof. Xu's research group has undertaken some other similar studies about land use changes. In their 2013 *An econometric analysis of changes in arable land utilization using multinomial logit model in Pinggu district, Beijing, China*, Pinggu, one Beijing district adjacent to Hebei and Tianjin, is the study area. Pinggu has been included in Three North Project as well since 2002 (China National Development and Reform Commission, 2001). Also, the increase of forestry land at the expense of the decrease in arable land can also be observed in Pinggu. Therefore, these two studies are comparative with respect to their research backgrounds. With more emphasis on ecological and geographic factors on land use changes, the Pinggu study has not considered the spatial autocorrelation. Table 11 summarizes the differences in the empirical results for driving factors of land use changes Pinggu and Zhangjiakou.

Table 12. Comparison between Pinggu and Bashang empirical results

	Pinggu	Zhangjiakou
Model:	Multinomial logit model	Revised spatial lag model
Consider spatial autocorrelation?	No	Yes
Significant spatial autocorrelation?	NA	Yes
Dependent variable:	Arable to forestland	Changes in forestry coverage
Independent variables:		
Slope	0.2915***	-0.175
Elevation	0.0246***	0.112***

Table 12 (cont.)

Population density	0.1422***	NA
Urbanization rate	-0.0115***	NA
Distance to roadways	-0.0001***	NA
Distance to rivers	-0.0003***	-0.005***
Distance to settlements	0.0004***	-0.002**
Distance to highway	NA	0.003***
Distance to county borders	NA	0.006**
Constant	-4.6365***	-65.542***
Rho	NA	0.946***
WyBorder	NA	0.0852***

When we compare the two studies in Pinggu and Zhangjiakou, it can be seen from Table 12 that the independent variables have similar effects in the forestation process. However, coefficients are more significant in Pinggu study, when spatial autocorrelation is not considered in the regression model. Even though some model specification tests still need to be done for Pinggu study, it can be anticipated that spatial autocorrelation also exists, since Pinggu and Bashang are not far from each other, and they are both included in Three North Project. Neglecting spatial autocorrelation will probably lead to considerable biasness in land use studies in China.

7.2 NON-GOVERNMENTAL FACTORS FOR LAND USE CHANGES

In this part of the study, I will concentrate on analyzing how these traditional factors play their roles in forestry changes in Zhangjiakou under the assumptions that county-level governments are interacting with each other in forestry construction, and they are trying to maximizing their revenues when they choose from different land uses.

As discussed in Chapter 4 of this study, a land parcel is likely to be converted into forestry use if this land parcel is under urbanized, has high elevation, and has easy access to water and transportation systems, even though agricultural land would occupy more lands that are near to water bodies and highways. Moreover, new forestry sites should be far away from county borders since county-level governments are likely to make the positive forestry externality internal to themselves, instead of sharing this externality with their neighboring counties. I will discuss in detail how the empirical study can be related with my hypotheses on location of the new forestry land.

(1) Distance to highway system

I made the hypothesis that land parcels away from the highway system are more likely to be converted to forestry land. The empirical study of this paper supports this hypothesis. The coefficients for distance to highway are all significantly positive in OLS, spatial lag and revised spatial lag regressions.

A possible reason for this positive relationship between the forestry coverage and the distance to highway system is that the northeastern part of this city does not have as dense highway systems, as it has been mentioned in Chapter 4 of this thesis. This area, where Yin Mountain is located, is naturally more sloped and suitable for forestry construction. As it can be seen from Figure 3, there is a continuous forestry area constructed in the Yin Mountain area, where the highway system is not so developed as other parts of Zhangjiakou city.

The fact that the new constructed forestry areas tend to be located far away from the highway system would probably lead to the difficulty in maintaining the young trees, especially the trees located in the mountainous areas.

(2) Distance to water

Chapter 4 of this study predicts that the nearer a land parcel is to a water source is, the more likely this land parcel would be developed into forestry land. The empirical study supports this prediction, since the coefficients for distance to water are significantly negative in OLS, spatial lag and revised spatial lag models. Since Zhangjiakou city, especially Bashang area, has pretty low level of annual rainfall, short distances to local water source may be crucial for the easiness of maintenance and for survival of the new trees.

(3) Distance to county border

I make the hypothesis in Chapter 4 that land parcels far from the county borders are more likely to witness increase in forestry coverage since this may be the strategy of county-level governments to make positive forestry externality internal, instead of sharing the externality with their neighboring counties. This prediction is also supported by the empirical study.

Up to now, considering the positive spatial lag parameter, different spatial autocorrelation within and across counties, and the tendency that new trees are located far from the county borders, it would be reasonable to say that county-level governments are interacting with each other in forestry construction. Even though I cannot yet find systematic evidence to conclude if the interaction is efficient or not, some signs of deforestation after 2000 would probably reveal the problem that county-level governments, even though reach or exceed their goals of the total forestry coverage, have not paid enough attention to locate the trees to where they are most likely to survive.

(4) Elevation

The empirical results of this paper support my hypothesis that the higher elevation is, the more likely a land parcel will have higher forestry coverage. The high elevation areas in Zhangjiakou are generally in Bashang, where the climate is unsuitable for mass agricultural production. Therefore, the construction of forests in high elevation areas will lead to smaller opportunity cost.

(5) Urbanization

The empirical study of this thesis does not support my hypothesis that the new forestry land should be located away from the urbanized areas. The reason for this phenomenon is probably that new forestry area in the middle area of Zhangjiakou is so close to the biggest urban site, which is in Xuanhua County. Therefore, the urbanization process is likely to be impeded because of the existence of new forestry lands.

7.3 OVERVIEW OF LAND USE CHANGES IN CHINA

As it has been mentioned in Chapter 1, land in China is strictly under governmental control. Therefore, Three North Project, as a national project for forestry construction, will have far-reaching influence on land use changes in the provinces included. Sometimes, the spatial autocorrelation in forestry increases does not only originate from ecological and geographical factors, but county-level or town level governments' interaction can be the source for positive autocorrelation as well.

The governmental interaction can cause undesirable outcomes for local environments, since some ecological factors are not given adequate consideration when new forests are constructed. I currently cannot utilize an appropriate evaluation method to testify if governmental actions in this case would be efficient or not. However, after 2000, unofficial reports reveal that a large area of the new planted trees actually has great difficulties in survival in Zhangjiakou. For instance, according to Hebei News Agency (2013), in Bashang area, underground water level has been dropped since 2000, and the annual rainfall level stays around 350 mm for the past decade. As a result, without adequate water supply and maintenance, the newly constructed forests have great difficulties in survival. For example, according to the report from Hebei News Agency (2013), 90% of the poplars in Zhangbei died after 2000 because of scarcity of water. The same problem also exists in other Bashang counties as well. To prevent undesirable outcomes of county level governments' interaction, the forestry construction can be planned by higher level governments, and enforcing the cooperative relationship between county level governments can prevent wasteful or inefficient competition as well.

Later studies in this area can enrich the dataset and extend the study period to recent years. If longer study periods can be incorporated, then it would be easier to discover how county-level governments' strategies in locating the new forests can exert long-term effects on the forestation process. Moreover, with more detailed information about the tree types and the soil conditions, it is possible to simulate an optimal map of forestry locations. By comparing the optimal map and the current land use map, it would be easier to discover if the decision-makers are deviating from their ecological concerns of forestry constructions.

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